THE JOURNAL

—OF THE—

FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

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VOL. CXXXIX.—Nos. 829-834.

JANUARY-JUNE, 1895.

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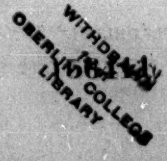

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JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS

VOL. CXXXIX. JANUARY, 1895. NO. 1

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

THE ANIMAL AS A PRIME MOVER.

BY R. H. THURSTON.

PART I. THE HUMAN ANIMAL AS A VITAL PRIME MOVER AND A THOUGHT-MACHINE; THE ENERGETICS OF THE VITAL MACHINE; ITS TRANSFORMATIONS.

The Vital Engine, the body of every vertebrate animal—from the human ruler of all, down to the lowest organism having a cartilaginous frame—is to-day well recognized, as, in the engineer's classification, a "prime motor," in which the latent forces and energies of a combustible "food," of a fuel, as many suppose it, are evolved, transferred and transformed to perform the work of the organism itself, to supply heat to keep it at the temperature necessary for the efficient operation of the machine, and for the performance of external work. The value of the machine as a prime mover is dependent upon the relation between this external work, so far as it can be applied to useful purposes as labor, and the

costs of its production in fuel or energy supply, and in wear and tear and replacement, precisely as with any other machine of the class, whether the source of power be chemical, thermal, electrical or vital.

The work of the machine is, however, a very different quality and is vastly different in quantity, useful work being compared with supplied energy and incidental expenditures from that of any other known motor. In the water-wheels and windmills, the office of the motor is simply that of transfer of energy of flowing currents of fluid, of water or of air, and, without transformation, to mechanism suitable for giving it useful application. The heat engines develop energy previously "latent," potential, as the modern nomenclature would call it, into the kinetic form of thermal motion, and by transformation, so far as may be practicable, into the dynamic form, make it available for work. Electro-dynamic machinery similarly makes available by transformation the energy of the electric current; and none of these machines has any other function than that of making useful some one energy previously stored by the operations of Nature in such form as to be readily applied to his purposes by the hand of man.

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The vital machine, on the other hand, has purposes and performs offices of essentially different kinds. It must not only transform the latent energies of the supplies received by it into useful external work, but all its work being directed toward the sustenance and preservation of the contained soul, as its principal and always essential purpose, all its operations being automatic or self-directed, all its powers of transformation of energy are demanded for the production, by transformation, presumably, of (1) the vital forces and energies; (2) the physical energies demanded in constructing, rebuilding and operating the animal frame; (3) the external work required to furnish the body supplies, to protect it from decay or injury, and to minister to the physical wants and ethical requirements of the personality of which it is at once the home and the vehicle.

This curious prime mover is thus an apparatus which,

from familiar sources of energy, transfers and transforms, for its own purposes and applications, a variety of energies, performing a variety of work in various realms. The nature and composition of the sources of latent energy, always chemical compounds capable of oxidation, are well known; the character and method of many of the internal, as well as of the external expenditures of energy, are equally well understood; but there are a variety and considerable number of internal operations, involving transformations of energy, the nature and method of which are entirely beyond observation by any process of experimentation yet devised.

"Food" is taken into the body, enters into solution with the peptic fluids, elaborated from previously supplied nutriment, is absorbed into the circulation, and disappears from our sight and reach; heat, carbon-dioxide, vapor of water, various salts, and a considerable proportion of unutilized nutriment, are rejected from the system, and work is performed as the product of transformed energies and in large amount, both within the machine and upon external bodies. A chain of energy transformations is in continuous operation, of which we see the two ends, so far as the vital machine is concerned, but of which we only get occasional glimpses between the extremities, and some of the links of which are, as yet, undiscovered and unknown. It is certain that the series of changes, material and kinetic, involves familiar methods of transformation, and it is hardly less certain that singular and probably wonderful and unknown processes of energy development and transformation are concealed within this miracle among machines.

Possibly a study of the present state of scientific research, relative to this machine, may give at least some idea of the importance and complexity of the problems here placed before the man of science and the engineer, if not give a clue to their final solution.

The source of power in the animal machine is invariably the stored chemical energy of vegetation, the potential energy of the hydrocarbons and other compounds contained in all plants, and capable of uniting with oxygen, to form carbonic acid, water, and salts capable of solution in water.

It is possible, but perhaps not probable, that other substances and energies forming constituents of these compounds may exist, having eluded the investigating chemist and physicist; but this is thought unlikely. We probably know precisely what enters the animal prime motor, and what are the sources of all its energies. Food and air are the two known elements of all its powers. It is also possible, but probably not the fact, that this machine may drink in from the surrounding ether some portion of its energy in forms still undetected and unsuspected. We are compelled, for the present, certainly, to assume that all the energies developed and applied in the vital machine are initially latent in vegetable matter, air and water. This organic substance is derived, by the carnivorous animals, indirectly, through the other creatures, all of which live upon vegetation directly. The organic forces of plant-life derive all energy from the inorganic world of minerals, and from the gases of the atmosphere, by utilizing the primary energy of solar rays in the chlorophyll with which every leaf is provided, as the active agent in that transformation. The vital machine thus ultimately derives all its energies from the sun.

Food is the material in which are stored the substances supplied to the vital machine as the reservoir of the potential energy from which the required energies, in various active forms, may be derived, as demanded, to perform the work of the body and the mind. It consists of a mixture of edible and other matter, the former being that part from which energy is derivable; the latter being indigestible and unassimilable, and only useful in promoting, by mechanical irritation, the action of the digestive system.

All foods contain:

Water; required for solution of nutrients.

Nutrients—protein, fats, carbohydrates.

Innutrient matter.

Protein consists of the albuminoids, and, in vegetable matter, the amides, a less valuable portion of the food. The white of egg, the fibrine of meat, and the gluten of wheat, are illustrations of albuminoid compositions.

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Fats, such as those of meat, and the greases of vegetation, the oils of the animal and vegetable compounds, extractable by ether, constitute the basis of construction of the fats of the body and of a part of the nerve and brain substance.

Carbohydrates are the starches and sugars of the vegetable.

Salts are found in both animal and vegetable foods, and are, in some cases, essential elements of the compositions making up the body, though not, in the ordinary sense, digestible and nutrient.

Mineral matters constitute, in the case of the vegetable foods, the principal portion of the innutrient matter of food, and form the ash when the plant is burned. In some cases these mineral matters serve as stimulants to digestive and other physiological processes, even when not themselves in any degree digestible, and are, for that reason, essential constituents of food. It is for this reason, largely, that vegetable foods are indispensable to perfect action of the functions and to bodily and mental health. The vegetable food also, especially the fruits and grains, contain the required elements of all the compositions of the animal system in best proportion, and best arranged for utilization by man and all other except the purely carnivorous animals. Could the whole animal be used as food, including blood and nerve and bone and brain, animal food would be substantially correct in composition; but itwould still lack the stimulating property of the other class of foods which comes of the presence of the mineral and indigestible elements.

The uses of food are mainly two: (1) To supply material for the building up and the repair and maintenance of the tissues of the body; (2) To furnish the energies required in the operation of the animal machine in their various forms and in due proportion.

The first is the direct application of a portion of the food; the second disposition of the elements of the food and their potential energy may be direct, as probably in the use of the fats, the combustion of which to carbon-dioxide and water results in the production of immediately available

energy; or it may be indirect, as where the carbohydrates are first digested and, later, consumed in similar manner to the fats; or, still more indirectly, as where the protein becomes first a part of the flesh, or of the nervous system, and, later, broken down in the course of the work of the body, serves as fuel or otherwise in the production of heat or other energy by its oxidation.

Protein forms tissue, muscular, nervous and other. Fats form a part of the nervous tissue, and carbohydrates are converted by the digestive organs into fats, and then serve the same purposes. Both the latter compounds serve as fuel or energy-storing reservoirs, contain a quantity of potential energy, which is, sooner or later, drawn upon in the development of the various energies utilized in the operations of the body and the brain. It is usually assumed that the energy demanded is that of thermal molecular motion and that the value of the foods may be measured by their calorific content or potential thermal energy. Until it is known just what energies are employed in the numerous and varied operations of the living creature, and to what extent they are severally derivable from the potential energy of the various foods, and transformable from one into another, and especially from or into thermal energy, no better method can be devised than that which assumes the value of foods, properly compounded in imitation of Nature's known proportions—as in milk for children, fruit of palatable character, and grains for adults—to be proportional to their calorific measure. Pure carbon, or the pure carbohydrates, however, are not foods in a proper sense, as they could not be converted into muscle, nerve or bone, and only serve, in themselves, for energy-storage for use by a body composed of protein largely, and of other essential matter in less proportion. On the other hand, the muscle and nerve and bone-making constituents, alone serve to build up the machine, but not to operate it. Ultimately, however, it is supposed that the stored energy of the latter class of compositions become available, and thus both, the original proportions being correct, may have a kind of measure of value in that of their fuel constituents. For highest efficiency,

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the proportions of the constituents must be suitable for the individual case, and availability by digestion and assimilation, and in the provocation of all essential vital processes, is quite as essential as either of the other required qualities of the food.

The protein compounds are all nitrogenous, whether in the form of albumen, fibrine, casein or gluten. These compounds are fairly uniform in value. The carbohydrates differ greatly among themselves in this respect; the fats are substantially of equal value as measured by thermal contents, but differ in palatableness and digestibility, and thus in food value. Neither the carbohydrates nor the fats contain nitrogen, and they are simply useful in furnishing a supply of heat or other energy. One unit weight of carbon and one of protein yield substantially equal quantities of energy, about 14,500 *B.T.U.*, or 1,860 calories per unit weight. Its energy is sufficient to raise 2,850 tons one foot high. The same weight of carbohydrate has usually very nearly the same force-value. A similar weight of fat should have 50 per cent. more stored energy—about 4,700 foot-tons. A pound of corn-meal should supply a quantity of energy equal to two-thirds that of an equal weight of carbon, about 2,080 foot-tons, 1,360 calories.

The food consumed daily by a powerful working man contains, on the average, about 3½ ounces of protein, 6 ounces of fat and 14 ounces of carbohydrates, according to Professor Woods. Its energy measures sensibly the same as that of 2½ pounds of corn-meal. Its protein and fats come largely from the flesh-food contained in the daily ration. The carbohydrates come entirely from the vegetable constituents. Another illustrative example of a ration given by the same authority measures 3·8 ounces of protein, 5 ounces of fat, 15 ounces of carbohydrates. The energy stored in the food thus taken measured 5,400 foot-tons or 3,530 calories. A standard ration for swine contains about 7,500 foot-tons, 4,900 calories per 100 pounds weight. That for cows measures 4,600 foot-tons, 3,000 calories, approximately, per 100 pounds weight. The ration for sheep measures 5,900 foot-tons and 3,550 calories per 100 pounds.

Food-energy transformation is the office of the vital machine. The fish can traverse the water all day; the bird can fly through the air all day; man and the animals on land can walk all day; and it is evident that, as suggested by Pettigrew, their tasks must be not very far different in magnitude. All exert powers approximately proportional to the volume of the seasoned working muscles employed in these tasks, which, according to various authors, is not far from about the equivalent in work of one atmosphere, fifteen pounds, per square inch of section of fibre, rising to somewhat higher figures; but all are very moderate intensities as compared with those adopted in machinery and in proportion to weights developing them. None can, therefore, find in peculiar tenacities or intensities of action of working parts a means of attaining remarkable power, even in the case of the bird, which was formerly supposed to enormously excel all other creatures in its concentration of power in mass and muscle. We seem thus reduced to the study of the methods of transformation of energy of the foods. The fact that venous blood is warmer than arterial, though very slightly, is another evidence that the transformations of matter, as well as of energy, in these processes, occur in the muscular system; and the path into which investigation must be turned would seem to be fairly well located.

Dr. Carpenter was, perhaps, the first to elaborate fully and clearly the idea that the germ of the organism is not the concentrated essence and energy of the organism and all its progeny, but that it is rather constituted as "a directive agency, thus rather representing the control exercised by the superintendent builder, who is charged with the working out of the design of the architect, than the bodily force of the workmen who labor under his guidance in the construction of the fabric." The actual constructive force, he thinks—as we now can see, very possibly, wrongly—is heat.*

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* "Thus in the case of the successive viviparous broods of the *Aphides*, a germ force capable of organizing a mass of living structures which would amount (it has been calculated) in the tenth brood to the bulk of 500,000,000 of stout men, must have been shut up in a single individual, weighing perhaps

It may now be taken as certain that, as Dr. Carpenter asserted in 1850, "in some way or other, fresh organizing force is constantly being supplied *from without*" during the whole period of activity of the vital machine, which continues, by inheritance, to transmit the power of absorption and transformation and of direction of this absorbed energy, for all its various purposes, throughout the life of the whole line of its posterity, and that of the race.

Liebig, Carpenter, Grove, and others, have long ago prepared the way for the acceptance of the proposition that the organs of the animal which elaborate its powers constitute an apparatus fitted to simply divert the energy received as latent in the food and awakened by the chemical processes constituting digestion, assimilation and nutrition, and to direct it into its new channels in the form of heat, mechanical energy and vital power. Sir Benjamin Brodie found that the act of respiration, simply, did not sustain the temperature of the body, and that the action of the spinal column was essential to the normal development of heat. Helmholtz found the chemical changes greater in muscle in use than when at rest, and a larger proportion of waste, due the breakdown of tissue, to be produced. Beclard found the quantity of heat developed by voluntary muscular contraction greater when simply an effort is produced, as when grasping an object firmly, than when doing work, as by lifting the object. Matteucci found that muscles absorb oxygen and throw off carbon-dioxide when doing work, and in larger amount as more work is performed.

Dr. Flint, after a very beautiful investigation of the conditions of the muscular system and the changes of tissue, in the case of the pedestrian Weston, after a five-day's walk, as well as throughout equal periods during and before the tremendous effort which carried him over 117·5 miles at the mean rate of over four miles per hour of actual travel, concluded that "work is always attended with destruction of

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the $\frac{1}{1000}$th of a grain, from which the first brood was evolved," if the theory was true; and "the bodies of all men who have lived from the time of Adam to the present day must have been concentrated in the body of their common ancestor."

muscular substance;" "the direct source of muscular power is to be looked for in the muscle itself." He thinks that the muscular tissue "cannot be absolutely stationary, and disassimilation must go on to a certain extent, even if no work is done. This loss must be repaired by food to maintain life." That this is ordinarily, or at least may be, a very small proportion of the energy-effect, is evident from the well-known conditions of hybernation and by the fact that Dr. Tanner and others have fasted for forty days and more, with no great apparent loss of vital and essential strength, and seemingly at only the cost of accumulated fat disposed of as a superfluity, previously, in the spaces between the muscles. In the case of severe labor, as where a pedestrian continually exerted all his powers for days together, Flint has proven clearly that large quantities of muscular tissue are broken down.*

The proportion of nitrogenized or muscle-making food to non-nitrogenized, in the walk here referred to, was, as measured in units of energy, about as 5,700,000 foot-pounds to 39,000,000, or about fifteen per cent.; which figure will be recognized later as corroborated by other and independent methods of examination of this subject. The total absorbed energy would thus be about 11,000,000 foot-pounds per day, plus that derived by the breaking down of tissue to the extent of the total value of about 3,500,000 foot-pounds, 700,000 per day; that is to say, 11,700,000 foot-pounds of energy were supplied the system per day, when doing an extraordinarily large amount of work, both externally and internally.† But Weston is a small man, and probably ten per cent. should be added to make these figures comparable with those elsewhere given as the average for a working man, 10,000,000 foot-pounds. This gives a total of over 12,000,000 foot-pounds, or twenty per cent. of the estimated figure to be later computed for the average regular day's work. The

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*"The Source of Muscular Power." New York: D. Appleton & Co. 1878.

†The vital machine consists of about forty per cent. muscle, of which a half is water, 12·5 per cent. blood, 2 per cent. brain, and the remainder is skeleton and internal organs.

food taken averaged about twenty ounces, a pound and a quarter, but was somewhat concentrated, and stimulating in more than ordinary degree.

As remarked by Professor Foster,* "from many considerations, it is extremely probable that a chemical change, an explosive decomposition of more complex into more simple substances, is the basis of a nervous impulse." The energy thus developed is largely in this case employed in conveying the impulse along the nerve and in setting up muscular or mental evolutions and applications of energy at its extremity.

The introduction of chemical actions in the production of solution of the available constituents of the food is one of the essential elements of the extraordinarily perfect utilization of all its substance, of its complete digestion, entire absorption and thorough assimilation. Only from a state of solution could complete absorption or precipitation take place. Food undergoes "profound disruption" before it can become a part of the body or furnish it energy. "It would almost seem that the qualities of each particle of living protoplasm were of such an individual character that it had to be built up afresh from almost the very beginning."†

The presence of considerable quantities of phosphorus, especially in the nervous system of the animal, indicates that chemical actions may be very rapid, and possibly may especially indicate the resultant production of peculiar material and non-material output, as the electric current of the gymnotus, if not all animals, light in the fire-fly, the vital forces of all vital machines. The presence of water in large quantity points the same way.

The blood is the carrier and distributor of all potential energy from the dissolved material of supply, and the capacity of the blood-vessels is probably something of a gauge of the quantity of energy supplied the parts to which they lead, and of the mean rate of expenditure during their period of operation and restoration to normal condition of rest. Whether the nutriment and the potential energy

* Encyclopædia Britannica. Art. Physiology, p. 21.
† *Ibid*

thus conveyed supply energy directly, as supposed by Dr. Pavy and others,* or indirectly by the upbuilding of tissue later broken down and supplying directly the stock of energy needed for transformation, as supposed and probably experimentally proven by Dr. Flint,† the result is the same.

The influence of the form in which the potential energy is supplied the machine is well exhibited where, as in penal institutions like that of the State of New York, "experimental classes can be formed and the effect of the changes thus found practicable, observed and measured. The inverse ratio of food-supply to crime and to illness had long been recognized by students in anthropology and sociology; the fact that every variation of the quality of an ample food-supply produces an effect upon our moods, our powers and our ability to perform mental even more than manual work, is a daily observation with every one; and the suggestion has even been made that the selection of nutriments may be made to produce effects of economic importance in both directions—in making the human as well as the lower order of machine better as a motor, better as an intelligent worker, and even better as a thinker and as a moral creature—which lines of improvement are all essential to further progress in either direction. So far as both experiment and general observation have gone, at present, it may safely be stated there can be no question that the value, the power, the efficiency and durability of the mechanical and of the mental side of the vital apparatus are both influenced essentially by the nature of the material selected as the reservoir of potential energy, to be rendered kinetic and to be applied to useful purposes by it.

As indicated by Dr. Carpenter, in the middle of the nineteenth century, it would seem now certain that "*motor force* may be developed, like heat, by the metamorphosis of constituents of food which are not converted into living tissue;" while there is also no doubt that, in many cases at least, the disintegration of tissue which has completed its period of service in the organism may, precisely as does the digestion

* *The Lancet*, Nov. 25, 1876.

† *Journal of Anatomy and Physiology*, Oct., 1877.

of animal food, perform its part in the supply of potential energy to the system for utilization in vital and other operations. As the same great physicist and physiologist has stated it:

"The life of man or of any of the higher animals consists essentially in the manifestation of forces of various kinds, of which the organism is the instrument, and these forces are developed by the retrograde metamorphosis of the organic compounds generated by the instrumentality of plants.

"Thus, during the whole life of the animal, the organism is restoring to the world around both the materials and the forces which it draws from it; and after its death this restoration is completed, as in plants, by the final decomposition of its substance."

As was, perhaps, first stated explicitly, by Liebig, we find that the sources of all forces, powers, energies, in man and animals, are to be found in the food constructed by the plants out of mineral substances under the active energy of the sun's rays, which energy, becoming thus latent, is reawakened by the vital apparatus and directed into useful channels, constructing the whole animal machine, and doing all its work—muscular, thermal, electrical, vital, mental.

The quantity of energy imported into the vital machine, is, in any individual case, readily measurable. It differs greatly with the species, size, temperament and work, external and internal, of the animal, and very greatly with the efficiency of its apparatus of digestion and assimilation. While, for example, one man will live and enjoy life and do his full share of work on one pound of good food per day, another will often require two pounds or more; and, in some instances, in which disease had reduced the assimilative powers, as much as seven pounds have been demanded and still proved insufficient to supply the needed total energy of the system. For a healthy and hard-working man, Dr. Pavy gives two pounds of bread and 0·75 pound of meat as a fair ration for a day.* Moleschott gives a total of forty six ounces, or about twenty-three ounces in a dry state, and

* "Treatise on Foods."

sixty to eighty ounces of water in twenty-four hours. Voit gives 500 to 800 grams, or about seventeen to twenty-seven ounces of nutrient matter in the food taken*; and, on the same basis, eliminating wastes, the principal investigators give about 550 grams, nearly twenty ounces, as an average. Edward Atkinson gives from 2 to 2·75 pounds per day of common foods as dietaries on which life can be sustained and ordinary work done without strain; but he allows four pounds for what may be termed "good living."† Much of the food included in the bill of fare of the well-to-do citizen has no real value in nutrition; some of it is actually and often seriously detrimental, and some, possibly a large proportion, is simply superfluity and waste.

The food of a working man contains about 15 per cent. nitrogenous matter; that of a young child 20 per cent. Milk contains 25 per cent., uncombined water, as in the preceding cases, eliminated. Eighty-five per cent. of the food of the man is thus applicable to work, and 15 per cent. to muscle-making. Three-fourths of the child's food is suitable for work and production of fat; one-fourth for making muscle. An egg contains 11 per cent. fat, 17·6 per cent. albumen, and 1·5 mineral matter; or dry, 37 per cent. fat, 58 per cent. albumen and 5 per cent. minerals; *i. e.*, apparently nitrogenous matter constituted about 0·6 the total weight of the body. A large fraction of the food is thus required for work and heat, a small proportion for building up the machine, or for its repair.

Wheat is usually considered the most perfectly compounded of the grains adapted for the food of man. It contains, according to Scammel, 14·6 per cent. muscle-making elements, 66·4 per cent. heat-producing material, 1·6 per cent. nerve and brain food, and 17·4 water and waste. Oatmeal contains, respectively, 17, 50·8, 3 and 30·5 per cent. of these elements. The meats contain 20, 14, 2 and 64 per cent. Fish require little heat, obviously, and as food contain 20 per cent. muscle-making material, 1 per cent. fat,

* *Mott's Manual.*

† Thurston's "Animal as a Prime Mover," p. 76.

5 per cent. brain and nerve food, and 74 per cent. water and waste. Oysters contain two-thirds as much solid matter of substantially the same composition. On the whole, four times as much energy is supplied in good food for heat and work as for muscle-repair, and forty times as much as for brain and nerve.

Frankland finds the energy per pound of common foods to range from 2,000 or 3,000 British thermal units in the case of the lean meats, to about 7,000 with the grains and their flours, and to over 15,000 in the case of the solid fats. The underground vegetables, which can hardly be called foods, such as potatoes, cabbage, carrots, contain three-fourths to seven-eighths their weight water, and only supply from 800 to 1,800 British thermal units of energy. In foot-pounds of dynamic power, the figures are, 600,000 to 1,400,000 for the last-mentioned substances, 1,500,000 or 2,300,000 for the lean meats, 5,000,000 to 6,000,000 for the grain foods, and 12,000,000 for the fats per pound of nutriment digested. This comparison, however, gives no clue to their values as foods and as nutriment of the vital machine, since it is known that the heat-producing value is but a part of the question, and that the power of assimilating the elements of the body and of producing muscle, nerve, brain and bone is no less essential to the maintenance of the efficiency of the machine than the production of thermal or other equivalent energies. The grains have double the value of the meats as brain and nerve foods, and the coarse vegetables one-fourth the value of the grains in this respect. Butter and lard, the best heat-producers, have no value at all as muscle and nerve material.*

Voit and others give the correct proportion of these elements in good food as about 120 grams protein, 50 grams of fats, 550 grams of carbohydrates, a total of, say, 700 grams, about twenty-three ounces per day, as the requirement of a man doing a day's work at muscular labor. This provides not far from 3,000 calories of thermal energy by oxidation. Voit gives a total required energy in thermal

* Scammel. *Ibid.*, p. 74.

units of from 3,000 to 3,300 calories, Playfair from 3,000 to 3,700, and Atwater from 2,820 to 4,060 calories; or, collecting all the best authorities, we may say that 3,000 calories, about 12,000 B. T. U., may be taken as representative of the demand of the machine for energy when doing little external work, and 4,000 calories, about 16,000 B. T. U., when performing a hard day's work every day. This means the equivalent of one pound of ordinary coal for the first, and an equal weight of the best coal for the second case, burned completely and with, consequently, maximum production of thermal energy and dynamic power. One pound of fairly good coal, say, about 13,000 B. T. U. of energy, may be assumed as ample for the production of all the work and power, and all the active phenomena, internal as well as external, of the human machine, when doing a full day's work.

This is 10,000,000 foot-pounds, nearly, of *energy supplied.*

So far as now known, this food-supply and the oxygen required for its complete combustion, with some nitrogen and a minute quantity of mineral matter, constitute the total intake of the animal machine, except that a quart of water, more or less, is needed to dilute the circulating fluids of the system. The next question for our examination is: What amounts of energy are expended and utilized in the various processes of the operation, of maintenance and repair, and of performance of external work, useful and useless, in an average day, with its usual distribution of working time and rest?

The efficiency of the animal, considered as a machine, is now well understood to be dependent, in large measure, for any given individual, upon the character of the material in which the stored energy supplied it is presented. It is coming to be understood, also, that the same is true of the vital prime mover, considered as a thought-producer. It is well known, also, that this is an important element in the maintenance of that ideal state, "perfect health," to which we may approximate, but never absolutely reach, and the approximation to which measures approximation to maximum efficiency under otherwise most favorable possible condi-

tions. From this point of view it is interesting to study the following summary of the distribution of nutritive and of heat-producing elements in the best dietaries, according to acccepted authorities, that have been yet proposed. The nutrients, the nitrogenous matters, are classed as including the muscle of meats, the casein of milk, the gluten of grains; while the fats and carbohydrates are taken as purely heat-producing, and the following diagram and tables, from the report of 1893 of the Elmira Reformatory, gives the best condensed view of the data required that the writer has yet seen.*

The Standard Dietary for man is usually given as not far from a weight of 700 grams, of which about 60 per cent. is generally starchy food, 20 per cent. fats, and the remainder nitrogenous; the potential energy stored is about 3,650 calories.† But while the actual dietaries are commonly largely composed of animal food, it should be at all times remembered that the teachings of comparative anatomy and of general experience, so far as careful observation informs us, indicate that the vegetable starches and fats and proteins are more suitable for the animal prime motor, and even still more to the thought-machine, than the carnivorous foods.‡

It will be noted that the lower limit of supply ranges close upon 400 grams, 2,000 calories, 8,000 B.T.U., for little or

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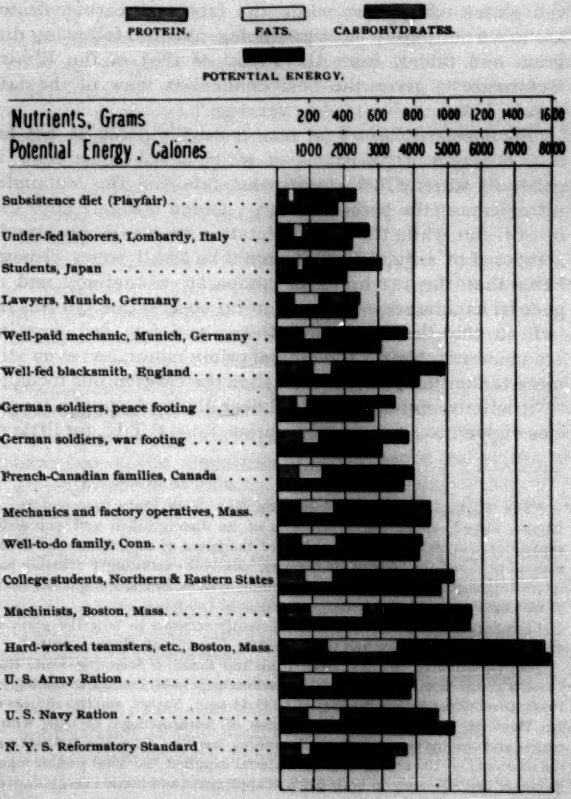
*The Eighteenth Year-Book of the New York State Reformatory, at Elmira, issued, under the supervision of its distinguished and successful superintendent, as wholly the product of the talent of its officers and of the manual skill and the taste of its inmates, contains exceedingly valuable and interesting accounts of the manual training system and trade schools there so fruitfully operated.

† For present purposes it will be sufficiently accurate to take the gram as one-thirtieth of an ounce and the calorie as four British thermal units.

‡ See particularly, Schlickeysen; Fruit and Bread, a Scientific Diet; Holbrook's translation, 1877. See, also, various papers of The Anthropological Institute of Great Britain, as that of C. O. Groom, Napier, and the address of Dr. Denis at the International Congress of Anthropology, of 1892; which papers and various researches now becoming familiar, show the influence of the character of the energy-storing material supplied the vital engine upon its power and efficiency in both fields of application of kinetic energy derived from the original store of potential.

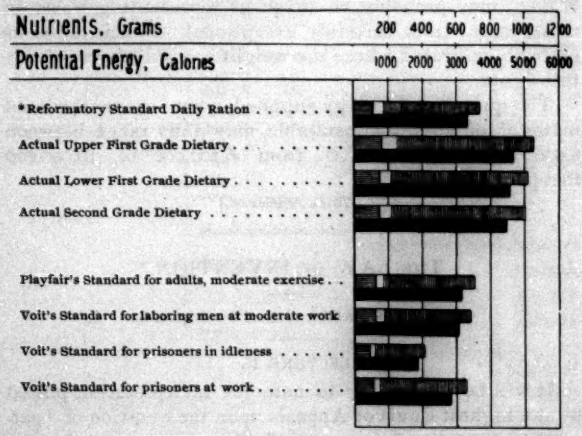
no labor; that it is not far from 600 grams, 3,000 calories, 12,000 B.T.U. for the working man; while double these figures may be reached.

I.—STANDARD AND ACTUAL DIETARIES.



On account of unavoidable waste, exact standards cannot be adopted in a practical ideal dietary, and it is universally deemed necessary to establish, beside an exact standard, an actual practical standard dietary, with somewhat increased allowance. The first table furnishes a comparison of certain daily dietaries computed principally by Prof. W. O. Atwater, and bearing upon people in various parts of the globe—together with lines indicating the theoretical standard dietary adopted in the Reformatory. The second table offers a comparison between this exact standard and the actual dietary as provided in three grades established at Elmira, and in contrast, other standards established by Playfair and Voit for adults in general, and for inmates of penal institutions.

II.—IDEAL AND ACTUAL PENAL DIETARIES.


Nutrients, Grams
200 400 600 800 1000 1200
Potential Energy, Calories
1000 2000 3000 4000 5000 6000
*Reformatory Standard Daily Ration
Actual Upper First Grade Dietary
Actual Lower First Grade Dietary
Actual Second Grade Dietary
Playfair's Standard for adults, moderate exercise
Voit's Standard for laboring men at moderate work
Voit's Standard for prisoners in idleness
Voit's Standard for prisoners at work

Exact figures corresponding to these lines are presented herewith:

NEW YORK STATE REFORMATORY DIETARY.

STANDARD DAILY DIETARY.

	Sunday.			Monday.			Tuesday.			Wednesday.			Thursday.			Friday.			Saturday.			*Weekly Total.*
*	b	d	s	b	d	s	b	d	s	b	d	s	b	d	s	b	d	s	b	d	s	Ounce.
C. Corned Beef	1·6						1·6						1·6			1·6						6·40
Beef					12			6									6			8		32·
Mutton											8											8·
Pork (fat)														1								1·
Kopf's Pea Soup		2																				2·
Bread	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	168·
Potatoes	6				12		6	4		6	4		6			6			6	4		60·
Onions								½		½	½								½	½		2·50
Turnips								1			2									2		5·
Carrots								1			1½									1½		4·
Parsnips								1			1½									1½		4·
Beets								½			½									½		1·50
Tomatoes																	2½					2·50
Flour					½						1½						1½			1½		5·
Oatmeal†								¼														·25
Beans				4				½						6								10·50
Barley								¼														·25
Rice								¾									1					1·75
Molasses																						31·
Totals, one week																						344·65
Totals, one day																			49·24			
Standard Daily Ration—Grams																						
Bread (actual average consumption per man per week in excess of Standard Ration)																						98·
Totals, one week																						442·68
Totals, one day																			63·24			
Actual Second Grade Daily Ration—Grams																						
Additional for Upper and Lower First Grades.																						
Coffee	¼			¼	¼		¼			¼	¼		¼	¼		¼			¼	¼		2·75
Tea			½			½			½			½			½			½			½	.88
Sugar	¼		¼	¼	¼	¼	¼		¼	¼	¼	¼	¼	¼	¼	¼		¼	¼	¼	¼	4·90
Totals, one week																						450·78
Totals, one day																			64·40			
Actual Lower First Grade Daily Ration—Grams																						
Additional, Upper First Grade.																						
Coffee		·2						·2									·2					·60
Sugar		·2	½			½		·2	½			½			½		·2	½			½	3·23
Dried Apples			½						½						½						⅛	2·50
Currants						¼						¼						¼				2·05
Butter			½									½						½				1·13
Cheese					2			2						2							2	8·00
Totals, one week																						468·49
Totals, one day																			66·92			
Actual Upper First Grade Daily Ration—Grams																						

TABLE OF FOOD VALUES.

	Refuse, Bones, Skin, etc.	*Water.*	NUTRIENTS.						*Potential Energy.*
			Protein.		*Fats.*		*Carbohydrates.*	*Mineral Matter.*	
	Per Cent.	Per Cent.	Per Cent	Ounce.	Per Cent.	Ounce.	Per Cent.	Per Cent.	Calories.
C. Corned Beef	19·7	62·0	30·0	1·92	8·0	·51	—	—	358
Beef		44·0	13·8	4·41	21·7	7·94	—	0·8	2,608
Mutton	20·0	42·9	37·1	2·97	23·2	1·86	—	0·7	834
Pork (fat)	10·4	9·5	2·8	·03	76·5	·76	—	0·8	205
Kopf's Pea Soup			21·0	·42	17·0	·34	46·0	·92	246
Bread		32·7	8·9	14·95	1·9	3·19	55·5	93·24	15,417
Potatoes	10·0	78·0	1·8	1·08	0.2	·12	19·1	11·46	1,489
Onions									
Turnips									
Carrots	10·0	81·0	2·0	·39	0·2	0·4	6·0	1·17	192
Parsnips									
Beets									
Tomatoes									
Flour		4·6	11·1	·55	1·1	·05	75·6	3·78	518
Oatmeal†		7·7	15·1	·04	7·1	·02	66·1	·17	89
Beans		13·7	23·2	2·41	2·1	·22	57·4	6·00	1,042
Barley		18·0	10·5	·03	2·5	.01	67·0	·17	94
Rice		12·4	7·4	·13	0·4	·01	79·4	1·39	178
Molasses			—	—	—	—	63·0	18·90	2,197
Totals, one week				29·36		15·07		137·22	23,337
Totals, one day				4·19		2·15		19·60	3,334
Standard Daily Ration—Grams				119		61		556	
Bread (actual average consumption per man per week in excess of Standard Ration)				8·72		1·86		54·39	7,827
Totals, one week				38·08		16·93		191·61	31,164
Totals, one day				5·44		2·42		27·37	4,452
Actual Second Grade Daily Ration—Grams				154		69		776	
Additional for Upper and Lower First Grades.									
Coffee									
Tea									
Sugar		2·2	0·3	·01	—	—	96·7	4·35	507
Totals, one week				38·09		16·93		195·96	31,671
Totals, one day				5·44		2·42		27·99	4,524
Actual Lower First Grade Daily Ration—Grams				154		69		794	
Additional, Upper First Grade.									
Coffee									
Sugar		2·2	0·3	·01	—	—	96·7	3·12	363
Dried Apples									
Currants									
Butter		10·0	1·0	·01	85·0	·96	0·5	·01	254
Cheese		41·3	38·4	3·07	6·8	·54	8·9	·71	583
Totals, one week				41·18		18·43		199·80	32,871
Totals, one day				5·88		2·63		28·56	4,696
Actual Upper First Grade Daily Ration—Grams				167		75		810	

* b—breakfast. d—dinner. s—supper.

† The writer has, as a matter of experiment, lived for long periods of time on about twelve ounces per day of oatmeal (dry) or the equivalent in "cracked wheat" or other grain, supplying but about 1,400 calories per day, and, leading sedentary life, found this allowance ample. This is also the least costly of all foods, and the writer has known young men to live on 60 cents a week, making up the dietary of grain foods, mainly.

III.—ANALYSES OF ENERGY STORAGE.

	Nutrients, in Grams.			Potential Energy in Calories.
	Protein.	Fats.	Carbo-hydrates.	
Re'l't'y Standard Dietary Daily Ration[1] . .	119	61	586	3,334
Actual Upper First Grade Ration	167	75	810	4,696
Actual Lower First Grade Ration	154	69	794	4-524
Actual Second Grade Ration	154	69	776	4.452
Playfair's standard for adults, moderate exercise	119	51	531	3,140
Voit's standard for laboring men at moderate work	118	56	500	3,050
Voit's standard for prisoners in idleness . .	85	30	300	1,857
Voit's standard for prisoners at work . . .	105	40	500	2,852

[1] All food supplies are issued according to this standard dietary, *except bread;* which is unlimited. The average consumption of bread per man is somewhat in excess of one and one-half rations per meal, thus accounting for the increase in value of the actual ration over that of the Standard Dietary, which conforms very nearly in food-values to the standards of Voit and Playfair.

An excess above 600 grams, 3,000 calories, 12,000 B.T.U., may probably be taken as representing waste in most cases; it is certainly exceptional. Deficiency is as probably indicated where the weight is less than two-thirds this figure.

The quantity of energy supplied, where the method and material of supply are suitable, may thus range between 8,000 and 12,000 B.T.U., from 6,700,000 to 10,000,000 foot-pounds per day.

[*To be continued.*]

THE LAW OF INVENTION.*

By HORACE PETTIT, of the Philadelphia Bar.

LECTURE II.

It will be interesting to note the interpretation placed by the highest Court of Appeals upon the question of "patentable invention" in some of the recent cases, for the purpose of gaining an insight into the rules observed by the Supreme Court of the United States in the determina-

* Two lectures delivered before the Franklin Institute, November 10 and 24, 1893.

tion of this question. A careful examination evinces the fact that the judges are governed to a very large extent, if not entirely, by the rules which governed their worthy predecessors in deciding some of the leading cases where this question was involved. The tendency of the courts still to be governed by "practical results" in cases somewhat doubtful is apparent in the recent decisions; never substantiating the patent, otherwise invalid, on account of the practical achievements and the commercial success of the invention, but employing the fact of *practical success*, in cases otherwise doubtful, as an additional reason for supporting the validity of the patent.

One of the most interesting decisions of the Supreme Court of the United States within the last year or two, is that of Washburne & Moen Company *vs.* The "Beat-'em-all" Barb Wire Company, otherwise known as the Barb Wire Patent cases, reported in 143 U. S. Supreme Court Reports, p. 275. etc., decided February 29, 1892. This decision reversed the finding of the court below, and held the Glidden patent Nos. 157, 124, November 24, 1874, for an improvement in wire fences, to be valid.

I will be pardoned if I refer to this case somewhat in detail, which I do, believing the facts connected with the attempted anticipation of the patent to be instructive.

The claim of the patent is as follows:

"A twisted fence wire having the transverse spur wire *D* bent at its middle portion about one of the wire strands *a*, of said fence wire, and clamped in position and place by the other wire strand *s*, twisted upon its fellow, substantially as specified."

The appeal was from the decree of the Circuit Court of the United States for the Northern District of Iowa, which held that the patent was invalid. The bill filed relied upon certain decrees obtained in the courts of other districts against other defendants, and which were claimed to have established the validity of the patent. The main defence was that the invention was anticipated, and that the invention, in view of the anticipations, was not patentable.

When it is recollected to what an enormouns extent this

wire fence has been employed in the last few years throughout the vast plains of the West, as well as to a very large extent throughout the East, and when the fact is appreciated that the boundless plains by this means have been readily subdivided into large pasture fields for cattle, the fence operating as an effectual means for retaining the cattle in defined limits, and from straying perhaps for many miles from the ranches to which they belong, as they formerly did, it will be understood why the case was so hotly contested.

What did the patent cover? Nothing but a short transverse wire, coiled at its central portion about one of the wire strands of a twist of wires with its free ends projecting in opposite directions, the other wire of the strand serving to bind the spur wire in position to prevent lateral displacement. It was on this simple little contrivance that the great minds of the judges of the Supreme Court of the United States were called upon to pass. The defendants did not deny that they made a fence similar to that of the patentee. It was admitted that they did. A vast amount of testimony, documentary and oral, was produced. The strongest evidence in the case, to my mind, was the alleged anticipating patent granted to Michael Kelly, February 11, 1863, which was over five years in advance of the date of Glidden application. Kelly took small, flat pieces of iron or steel, each provided at its centre with a hole the size of the wire, so that they could be introduced on the wire. These pieces were strung on the wire at distances about six inches apart, and were compressed laterally by a blow of the hammer so as to flatten the hole and lock, as it were, these spurs upon the wire. He described the spur, or thorn, as being provided mainly upon a single strand of wire, though he said in his specification, and illustrated the construction in one of the drawings: "I can, where it is desirable *to increase the strength of the wire*, lay another wire of the same or a different size alongside of a thorn wire, and can twist the two by any suitable mechanism." He did not say that the twisting of these two wires was for the purpose of holding the spur in position and preventing lateral displacement, which Glidden said in his

patent would be the effect of the twisted wires, and the purpose for which he, Glidden, employed the additional wire; but Kelly employed it, as he states, "to increase the strength of the wire." It will be clearly seen, however, that even though Kelly did not say so, the effect of the wires thus twisted must have been the same, and must have aided in holding the spur in position, and preventing lateral displacement.

Mr. Justice Brown said, *inter alia*, in deciding the case: "The vital difference in the two patents is in the shape of the barb itself. In one case (Kelly) a flat bit of metal is used of an elongated diamond shape, through which a hole is pierced, by means of which it is strung upon the wire requiring something more than the aid of a second wire twisted upon the first, to render it immovable. In the other, the barb is a piece of wire coiled about one of the fence wires, and held rigidly in place by the twisting of another wire about the first." Substantially, the difference between Kelly and Glidden was that Kelly made his spur out of a piece of flat metal with a hole in the centre, placing it between two strands of twisted fence wire (in the alternative construction) and hammering down the sides to more firmly lock it in position, while Glidden made his spur out of a short piece of wire, giving it one or two twists around one of the strands of the fence wire and holding it in position from lateral displacement by the other twisted strand of fence wire.

This brings us down to what the Supreme Court of the United States construed to be *invention* in the early part of last year. It was more than the exercise of mechanical skill; it was more than calling into play the exercise of the constructive faculties. In the opinion of the court, it required the employment of the *inventive* faculties.

The views of the court upon the question of the patentability of the Glidden barb wire may be gathered from the following short extract from the decision:

Mr. Justice Brown, upon this point, said: "The inventions of Hunt and Smith (other references less pertinent than Kelly) appear to be scarcely more than tentative and

never to have gone into general use. The sales of the Kelly patent never seem to have exceeded 3,000 tons per annum, while plaintiff's manufacture and sales of the Glidden device (substituting a sharp barb for a blunt one), rose rapidly from fifty tons in 1874 to 44,000 tons in 1886, while those of its licenses in 1887 reached the enormous amount of 173,000 tons. Indeed, one who has travelled upon the western plains of this continent cannot fail to have noticed the very large amount of territory enclosed by these fences, which otherwise, owing to the great scarcity of wood, would have to be left unprotected.

"Under such circumstances courts have not been reluctant to sustain a patent to the man who has taken the final step which has turned a failure into a success. In the law of patents it is the last step that wins. It may be strange that, considering the important results obtained by Kelly in his patent, it did not occur to him to substitute a coiled wire in place of the diamond shaped prong, but evidently it did not; and to the man to whom it did ought not to be denied the quality of inventor. There are many instances in the reported decisions of this court where a monopoly has been sustained in favor of the last of a series of inventors, all of whom are groping to attain a certain result, which only the last one of the number seemed able to grasp."

Mr. Justice Brown here cited the case of the Webster Loom Company *vs.* Higgins, 105 U. S. 580, where an improvement in looms for weaving pile fabrics, consisting of such a new combination of known devices as to give to a loom the capacity of weaving fifty yards of carpet a day, when before it could only weave forty yards, was held to be patentable.

The barb wire case will suffice to illustrate what, in the opinion of the Supreme Court, in 1892, was necessary to constitute patentable invention.

The laymen who may be interested in knowing the amount of research which is involved in the defence of a well-tried patent suit, would do well to read the testimony produced in this case, as a fair illustration. The history of barbed wire fences was, in these cases, for the first time

completely set out. No such care is exercised in the compilation of facts in the preparation of the most authentic biographies of illustrious men, or in the compilation of detail in the preparation of the history of a great people. Not that I mean to say that this case—although most carefully prepared by eminent counsel—is a more shining example than other important cases, but merely cite it as an instance; and would also advise those seeking for such information to carefully read the testimony produced on the part of the defence in the attempt to invalidate the Bell telephone patent.

Since the jurisdiction upon appeal in patent suits has been generally taken away from the Supreme Court of the United States and conferred upon the Circuit Courts of Appeals of the various districts, it will be noted from the general line of decisions of the latter, that they have followed fairly closely the path which had previously been hewn out through the underbrush of difficulty by the Supreme Court of the United States, after many years of arduous labor.

"AFTER THE FACT."

The case of Webster Loom Company *vs.* Higgins, and the barb wire case, it may be noted, in passing, show clearly that in these two important cases of early and of late date respectively, the court was not influenced by a fault which many of the courts in deciding the question of patentability seem to have fallen into, of forming an opinion regarding the patentability of an invention "after the event," or rather "after the fact;" after the way is opened out, showing how to overcome the obstacles which now seem very clear indeed, though before a cloud intervened, which required the eye of the *inventive* faculty to penetrate. When the cloud is removed it is hard to appreciate that it ever existed, and, consequently, the courts are often led, in determining an apparently "border-line" case, to decide that the change was one of *mere mechanical skill*, and not one of invention. Although the invention may have resided in some apparently trifling change, it has *bridged the gap* between failure and success. It has opened up hitherto

unknown resources; viewed "*before* the fact or event," there was no way of accomplishing the end in the desired manner except through the assistance of the *inventive* faculty. Viewed *after* the fact the means employed for bridging the gap seemed apparent and simple, as do all the tricks of the prestidigitateur when explained, yet the courts *after the fact* frequently fail to conceive that there was invention in the device.

The case of Webster Loom Company *vs.* Higgins is here directly in point. The change from the old construction was apparently trifling when once known, but it required an inventor to make that change. In this case, it was said, that it was plain from the evidence and from the fact that it was not sooner adopted and used, that it did not for years occur in this light to even the most skilled persons. It may have been under their very eyes, they may almost be said to have stumbled over it; but they certainly failed to see it, to estimate its value and to bring it into notice. Now that it has succeeded, it may seem very plain to any one that he could have done it as well. This is often the case with inventions of the greatest merit. It may be laid down as a general rule, though not, perhaps, as an invariable one, that if a new combination and arrangement of known elements produce a new and beneficial result never attained before, it is evidence of invention.

In Consolidated Safety Valve Company *vs.* Crosby Company, 113 U. S. 157, it was said that Richardson's invention brought to success what prior inventors had essayed and partly accomplished. He used some things which had been used before, but he added just that which was necessary to make the whole a practical, valuable and economical apparatus. He added to his valve that part which was necessary to make the valve a success, and which very part the others lacked.

The fact that a device has gone into general use, and displaced devices for like purposes, does not establish the fact that the later device involves patentable invention. It may, however, always be considered, and when the other facts in the case leave the question in doubt, it is sufficient

to turn the scale. (Smith *vs.* Goodyear Company, 93 U. S. 486; Magowan *vs.* New York Belting Company, 141 U. S. 332.)

The question, What is invention? or sufficiency of invention to support a patent? is one upon which volumes have been written, and volumes more could be written, but it is unnecessary here is this brief paper to consider the question further. Sufficient has been said to point out the difficulties of formulating any fixed rule for determining invention, but from the rules which do exist, one skilled in the particular branch can, with a fair amount of accuracy, determine the question. To assume the dignity of a patentable invention the subject must be capable of involving the exercise of the *inventive* faculties, as contradistinguished from the *constructive* faculties, of the mind. Ingenuity must be apparent, but it matters not to what degree; it may be but the *spark* of ingenuity. It matters not whether the invention is the result of long and laborious research and study or whether it was conceived by a *single flash* of the inventive faculties.

APPLICATION FOR LETTERS-PATENT.

Having sufficiently considered, for the purposes of this paper, the question What is patentable invention? before attempting to discuss the different classes into which patents are properly divided, let us pause for one moment to consider in a cursory manner the nature of the proceedings in application for patents.

The application comprises a petition to the Commissioner of Patents, a power of attorney to the solicitor or attorney (where a solicitor or attorney is employed), a specification and claim(s), and an affidavit by the applicant setting forth that he believes himself to be the inventor, that the invention has not been on sale or in public use in the United States for more than two years prior to the date of his invention, and other detail. If the invention has been patented abroad prior to the date of application here, the countries and the dates of these patents must be stated in the oath. If the invention has been patented in foreign countries prior to the date of the issue of the United States pat-

ent, the term of the United States patent will be limited to the term of the foreign patent having the shortest term to run. As most foreign patents bear date as of the date of filing, great care must be exercised where the inventor desires to take out foreign patents, that the foreign applications shall not be filed before the United States patent issues; for, should the United States patent issue before the foreign is filed, the validity of the foreign patent in some countries will be affected. The better practice, and the one most generally followed in taking out a series of United States and foreign patents, is to issue in this country and file abroad on the same date. This is the general rule; of course, the laws vary somewhat in the different countries, and the applicant must be governed by the particular countries in which he is making application for protection.

The applicant should not expect to secure a patent in this country within five months from the date of filing; a patent is comparatively rarely issued within that time. In cases where exceptional dispatch of business is exhibited, both on the part of the Patent Office and on the part of the attorney, the time occupied might be something less, sometimes three months will see a patent through.

Sometimes it is the desire of the patentee to delay as long as possible the issue of the patent, for purposes of his own, and various methods of delay are resorted to for this purpose. I have personal knowledge of a patent on a feather duster which was not issued until thirteen years and nine months after the date of filing. The application for the Berliner patent, belonging to the American Bell Telephone Company, was filed June 4, 1877, and was not issued until November 17, 1891, a period of fourteen years and five months after the date of filing.

The term of a United States patent does not commence to run until the date of issue, and the patentee has no exclusive right in and to his invention until the date of issue, from which time, provided that his patent is valid, and that the invention has not previously been patented abroad, he has the exclusive right to the invention for the term of seventeen years.

The specification must describe the invention accurately and specifically, so that one skilled in the art to which it pertains can make and use the same. The claims are most important and must set forth specifically the essential elements or features which the applicant considers to constitute his invention; no more, no less.

CAVEAT.

If an inventor has conceived, but only partially completed his invention, and is apprehensive that before he shall complete the same, another may file an application for letters-patent for the same invention, what is he to do? The law provides him a remedy. He can file what is termed a "caveat."

A great many inventors, principally the inexperienced, of which there are a great number—have acquired the idea from some source that a caveat is a *cheap patent*. This is not the fact. A caveat is for *one* purpose, viz: *notice*. It gives no right to the caveator to prevent others from making, selling, or using his invention, during the life of the caveat, or at any other time, until he has secured and has had actually issued to him letters-patent. The law relative to caveats merely says to the inventor, substantially: If you desire further time to *mature* your invention you can file a caveat in the Patent Office, and if an application for a like invention is made during the life of the caveat you will receive notice of the same, whereupon you must file your application within a limited period specified.

Section 4,902 of the Revised Statutes says, substantially, that any citizen (or alien, if he has resided one year in the United States next preceding the date of filing, and has declared his intentions to become a citizen of the United States), who desires further time to *mature* his invention or discovery may, on payment of the fees file a caveat setting forth the design and distinguishing characteristics of his invention, and praying protection until he may have matured his invention, which caveat will be filed in the confidential archives of the Patent Office. A caveat is granted for *one* year from the date of filing, but may be renewed

from year to year, at the will of the caveator, If an application is filed for the same invention during the life of the caveat, notice is given to the caveator and he must file his application for a patent in three months from the time allowed for receipt of same by mail. If the claims are for the same invention an interference will be declared, and the case will be heard as on the usual interference proceedings in the Patent Office.

Cases have arisen where it has been shown by proof that the caveator did not receive the notice sent him by mail, and it has been held that as it was no fault of the caveator that he did not receive the notice he should not suffer, but that he was entitled to contest in the Patent Office the priority of his invention over the claims of the man who secured the patent, and if he should sustain his claims to priority he would be entitled to a patent. (Frevert *vs.* Gahr, 1873, 3 *Official Gazette*, 660). This was also substantially held in Ware *vs.* Bullock (1874, 7 *Official Gazette*, 39) Phelps *vs.* Brown (1859, 4th. Blatchf. 352).

The rule in reference to caveats applies only to notice of applications which are filed while the caveat is alive. Of those filed before the caveat and after it has expired by limitation, the caveator is not entitled to notice.

CLASSES OF PATENTS.

Patents are granted under Section 4,886 of the Revised Statutes for four classes of inventions therein noted, viz: an *art, machine, manufacture and composition of matter*. These may be resolved for the purposes of more condensed classification into three classes, viz: *process patents, machine patents* and *product patents*. An art in the patent law sense of the word is a method or process; machines form a class by themselves; a manufacture and composition of matter may be resolved into one class, and termed a *product*.

In addition to these classes of patents the law also provides for the granting of *design patents*, which will be hereinafter briefly referred to.

Process.—The word "art" employed in Section 4,886, as interpreted by the courts, has a much more restricted

meaning than the word as defined in the dictionaries. Again, a *process* must be distinguished from a *principle*. A principle is *not* patentable; a process is.

In determining what is, and what is not, a patentable process, necessarily some very fine points and distinctions become involved. The mere use or employment of a particular element of nature to do or operate a particular thing would *not* in itself be a *process* within the contemplation of the Act. In order to render it patentable, the thing achieved must in all cases, have involved the exercise, or been capable of involving the exercise of the inventive faculties of the inventor or discoverer; the adaptation or use of an electric current for printing intelligible characters at a distance conveys the distinction very fully to the mind, in a negative manner. This was decided by the Supreme Court *not* to be a patentable process. The great case of O'Reilly *vs.* Morse (15 How., 61), and the celebrated decision of Chief Justice Taney in this case has been referred to in very nearly all of the decisions since that date where the question of *process* was involved.

If a force of nature known or unknown is applied to a material physical object in a new way and brings about new physical results, it is clear that in order to accomplish this the faculties of the discoverer, known as the *inventive* faculties, must have been brought into requisition. The force of nature itself has with the material or physical object operated in a manner in which the two elements have never before been known to have operated. It is not always necessary that the resulting product shall be a *new* product, so long as the operation of the known force upon the physical or material object is new in the manner described and employed. (Foote *vs.* Silsby, 1849, 1 Blatchf. 445.) The practical application of a known force to a new object is a new art (Whitney *vs.* Mowry, 1867, 2 Bond. 45), and the practical application of a new, or heretofore unapplied natural force is a patentable process (Roberts *vs.* Dickey, 1871, 1 Off. Gaz. 4). A new mode of using old apparatus may constitute a patentable process. (Lawther *vs.* Hamilton, 1888, 42 Off. Gaz., 487.) Mr. Robinson in his work on Pat-

ents, Vol. I, Sec. 165, says: "An art may be either a force applied, a mode of application or the specific treatment of a specific object." An art may be fully within either of the three great fundamental groups of means according to the number of its essential factors and the subject of the process or discovery.

It is clear that the effect produced must be a *physical* effect.

The art of vulcanizing India rubber by subjecting it to a high degree of heat when mixed with sulphur and a metallic salt was a patentable process. Neilson's method of applying the hot blast to furnaces by forcing the blast through a vessel or receptacle situated between the blowing apparatus and the furnace, and heated to a red heat, was a patentable process. These patents were sustained after very able arguments on both sides.

In the case of Corning *vs.* Burden (15 How., 267), the court said: "A process *eo nomine* is not made the subject of a patent in our Act of Congress; it is included under the general term, 'useful art.' An art may require one or more processes or machines in order to produce a certain result or manufacture. The term 'machine' includes every mechanical device or combination of mechanical powers and devices to perform some function and produce a certain effect or result. But where the result or effect is produced by chemical action, by the operation or application of some element or power of nature, or of one substance to another, such modes, methods or operations are called 'processes.' A new process is usually the result of a discovery; a machine, of invention. The arts of tanning, dyeing, making waterproof cloth, vulcanizing India rubber, smelting ores and numerous others are usually carried on by process as distinguished from machines." Mr. Walker, in his work on patents, Section 6, defines the patent law meaning of a proces to be, "an operation performed by rule to produce a result by means not solely mechanical. Robinson on Patents, Section 159, defines it as follows: "An art or operation is an act or series of acts performed by some physical agent upon some physical object and producing in such

object some change either of character or of condition, it is also called a 'process' or a 'mode of treatment.'"

Mr. Justice Bradley in deciding the celebrated case of Tilghman *vs.* Proctor (102 U. S. 707), defined a process as follows: "Whoever discovers that a certain useful result will be produced in any art by the use of certain means is entitled to a patent for it, provided he specified the means."

In O'Reilly *vs.* Morse (15 How. 119), the court decided the eighth claim, which attempted to cover the use of the motive power of an electric or galvanic current for marking or printing intelligible characters at a distance, invalid and *not* constituting a *patentable process.* It was a claim for a new application of the electric current for that particular purpose. The court held that the claim was too broad and not warranted by law. Chief Justice Taney, in delivering the opinion, said: "No one, we suppose, will maintain that Fulton could have taken out a patent for his invention for propelling vessels by steam, describing the process and machinery he used, and claimed under it the exclusive right to use the motive power of steam, however developed for the purpose of propelling vessels. * * * Neither could the man, who first discovered that steam might, by a proper arrangement of machinery, be used as a motive power to grind corn or spin cotton claim the right of the exclusive use of steam as a motive power for the purpose of producing such effects." The learned discussion of the question of patentable process entered into by Mr. Justice Bradley in his decision of Tilghman *vs.* Proctor, above cited, has rendered the case justly celebrated.

As early as 1813 it was discovered by an eminent French chemist, M. Chevreul, that ordinary fat, tallow and oil were chemical compounds, and consisted of a base which has since become known as glycerine, and of different acids, termed generally *fat acids*, but specifically stearic, margaric and oleic acids. These acids in combination severally with the base glycerine, form, respectively what are termed stearine, margarine and oleine. These have all come to be valuable products, and the base glycerine when purified is a desirable article for many uses.

In 1853 Mr. Richard A. Tilghman, of Philadelphia, the complainant in the case, discovered that these fat acids could be separated from the base, glycerine, without injury to the glycerine, by the single and simple process of subjecting the neutral fat, while in intimate mixture with water, to a high degree of heat and under sufficient pressure to prevent the water from being converted into steam, without the employment of any alkali, or sulphuric acid, or other saponifying agent. The principal conditions were a constant and intimate commixture of the fat with the water, a high degree of heat, and a pressure sufficiently powerful to prevent the conversion of the water into steam. By this operation the fat acids were separated from their base, glycerine, and each element took up the requisite equivalent of water necessary for its separate existence; the glycerine, in solution, separated itself from the fat acids by settling to the bottom when the mixed products were allowed to stand and cool. A chemical change took place in consequence of the presence of water and the active influence of heat and pressure upon the mixture. The claim of the patent was as follows:

"The manufacture of fat acids and glycerine from fatty bodies by the action of water at a high temperature and pressure."

The patentee described in his specification a preferable construction of machinery for carrying out his process, referring also to the fact that certain other constructions could be employed. The defendants employed a different machine in carrying out the process from that described in the patent, but certainly did manufacture fat acids and glycerine from fatty bodies by the action of water at a high temperature and under pressure. They did employ some lime, but not enough to materially affect the process, and the degree of temperature employed by them was not the degree of temperature preferably used by the patentee. After a careful review of the facts and the law in an opinion by the late Mr. Justice Bradley, the claim was decided valid. In deciding the case he said, *inter alia*, "Had the process been known and used before, and not been Tilghman's

invention, he could not then have claimed anything more than the particular apparatus described in his patent, but being the inventor of the process, as we are satisfied was the fact, he was entitled to claim it in the manner he did." And after reviewing the leading cases upon the subject, such as Corning *vs.* Burden, Neilson *vs.* Thompson and O'Reilly *vs.* Morse, he further said:

"It seems to us that this clear and exact summary of the law affords the key to almost every case that can arise. Whoever discovers that a certain useful result will be produced in any art by the use of certain means is entitled to a patent for it, provided he specifies the 'means.' But everything turns on the force and meaning of the word 'means.' It is very certain that the means need not be a machine, or an apparatus; it may be, as the Court says, a process. A machine is a thing. A process is an act, or a mode of acting."

From this brief review of the subject of "process patents," we may conclude by saying that a process may be said to be a directing or training of a force in a given manner through the medium of physical agents applied to material objects whereby are produced material effects.

Machine Patents.—The question "What is a *machine?*" is not so abstruse as the question involved in the consideration of "What is a process?" Every one knows what a machine is. In the common acceptation of the term, it is a device composed of one or more parts for performing mechanically certain operations; as to whether the machine is new or not, or sufficiently novel to render it patentable over the prior art, is the important question involved in most cases in which machine constructions are concerned. Patents are constantly granted for *improvements* upon machines in their minutest details, provided the improvement is novel and useful and is capable of the exercise of the inventive faculties. The word machine, in the patent law sense, is broader than in the ordinary acceptation of the term.

Manufacture.—This is a very broad term, as broad almost as its derivation implies, not including, however, machines

or compositions of matter. Under this class patents have been granted for the construction of houses, and other constructions of buildings. This will give some idea as to the extent to which the term has been carried in the granting of patents.

Composition of Matter.—A composition of matter is usually a product formed by the chemical action of its ingredients, though it may be a product composed of various parts of matter mechanically united. A composition to be patentable must, in its entirety, produce different results from the aggregate, independent results of the respective ingredients. The ingredients in the combination must lose their individuality and produce different effects in the combination than they produce separately and as independent organisms. This class opens a wide field for litigation, as well as controversy, in the applications for patents. A *composition* may be composed of, let us say, five ingredients. A composition may subsequently be invented or discovered in which like or better effects can be produced in the product by leaving out one of the material ingredients of the other product; and thus will be composed of four ingredients only. Yet this composition will be patentable, notwithstanding the existence of the former composition, and will not infringe the former composition if there is in it no equivalent for the fifth ingredient of the first composition, and if the eliminated fifth ingredient performed an essential and material function in the old invention. In this view of the case, it must be presumed that the new composition produces a somewhat different result. From this one illustration it can be seen how large a field for litigation and controversy exists. This illustration is an extreme case, though a true one.

It will be unnecessary to further consider the subject of "composition of matter" here, or to dwell at greater length upon the consideration of the four classes over which we have briefly passed.

The Hon. Commissioner of Patents Butterworth in *Ex Parte* Blythe (1884, 30 *Official Gazette*, 1,321), suggests that there exist under Section 4,886, of the Revised Statues,

eight classes of patents, instead of the four mentioned, constituting the additional four by adding to each of the original four classes the word "*improved*," viz.: a new art, a new machine, a new manufacture, a new composition of matter, an improved art, an improved machine, an improved manufacture and an improved composition of matter, making eight in all. This, as it is seen, is a mere duplication of the four original classes with the word "improved" added.

DESIGN PATENTS.

This class of patents is almost too broad a subject to touch upon in the remaining time allotted to me. Suffice it, however, to briefly note that it is provided for in a separate section of the Revised Statutes and is distinct from the classes included in Section 4,886.

Section 4,929 provides as follows:

"Any person who, by his own industry, genius, efforts, and expense, has invented and produced any new and original design for a manufacture, bust, statue, *alto-relievo* or *bas-relief*, any new and original design for the printing of woollen, silk, cotton, or other fabrics; any new and original impression, ornament, pattern, print, or picture to be printed, painted, cast, or otherwise placed on or worked into any article of manufacture; or any new, useful, and original shape or configuration of any article of manufacture, the same not having been known or used by others before his invention or production thereof, or patented or described in any printed publication, may, upon payment of the fee prescribed, and other due proceedings had the same as in cases of inventions or discoveries, obtain a patent therefor."

A patent for a design differs at least in one important respect from patents of the other classes heretofore noted and provided for under Section 4,886, in that the invention receives its protection, not on account of its *functional utility*, but on account of its *appearance* and *ornamental effect*. In other words the classes provided for in Section 4,886 are of utilitarian value, while that provided for in Section 4,929 is of value as an *ornament* or on account of its *pleasing effect*.

For some strange reason the word useful became incorporated in Section 4,929, it says: "Any new, *useful* and original shape or configuration of any article of manufacture." But by judicial alchemy this word "*useful*" has been decided to mean not useful in a *functional* sense but that it means *ornamental utility*. It seems to me clear that the word is there by mistake, but it cannot be erased by the courts, so it must be resolved into meaning something which it would not commonly be accepted to mean. This Section of the Act was apparently passed to cover ornamental objects which could not receive any protection under Section 4,886, but a careful examination of the weekly issue of patents shows that patents are frequently granted under this design Act for the shape or configuration of manufactures and parts constructed purely for functional purposes. Looking at the subject, however, in the light that the inventor requires all the protection which he can possibly secure, it is probably a wise divergence from the spirit and intention of the Act, though within the letter of the law. The question of identity in design patents is determined by a very materially different method of criticism and investigation from that employed when the identity of functional patents is involved. In the latter class of cases experts trained for the purpose critically analyze the essential features or constructive parts and compare them with each other, noting carefully their operation and object. In the former class, viz.: design patents, the question of identity is determined by the effect on the eye of an ordinary observer, expert comparative testimony is rejected. The question is: Does the alleged new design strike the eye of an average observer as being the same as the design with which it is compared; does the alleged infringing design, in the case of litigation strike the eye of the ordinary observer as the same thing as the design patented?

One of the leading cases, if not *the* leading case, bearing upon design patents is that of Gorham Company *vs.* White (14 Wallace, 511) which contains the views of the Supreme Court of the United States upon the subject, as set forth clearly in an opinion by Mr. Justice Strong. Mr.

Justice Strong, in delivering the opinion of the court, said:

"The Acts of Congress authorizing the granting of patents for designs were plainly intended to give encouragement to the decorative arts, they contemplate not so much utility as appearance, and that, not an abstract impression or picture, but to an aspect given those objects mentioned in the acts. It is a new and original design for a manufacture whether of metal or other material; . . . the law manifestly coutemplates that giving certain new and original appearances to a manufactured article may enhance its saleable value, may enlarge the demand for it, and may be a meritorious service to the public. . . . It is the appearance itself which attracts attention and calls out favor or dislike. It is the appearance itself, therefore, no matter by what genius caused, that constitutes mainly, if not entirely, the contribution to the public which the law deems worthy of recompense. . . . Plainly it must be sameness of appearance (to produce identity) and mere difference of lines in the drawing or sketch, a greater or smaller number of lines, or slight variances in configuration if sufficient to change the effect upon the eye, will not destroy substantial identity."

Mr. Hector T. Fenton, of Philadelphia, in his work on Designs, states (Sec. 15): "The law of combination is equally applicable to designs. As in mechanical devices, a mere aggregation of designs like a mere aggregation of mechanisms do not constitute patentable combinations arising to the dignity of invention. . . . (Sec. 20) Unity of design constitutes another very important question in design cases, and it may be laid down as a general rule that where there is no necessary connection between two designs or parts of a design, there is an absence of unity to render them a single patentable design."

Patents for designs also differ from functional patents in the length of the terms for which they may be granted. Design patents may be granted for the term of three years and six months, or for seven years, or for fourteen years, as the applicant may elect, but he is bound in his application to elect the term for which he desires protection; when the

patent is once issued the term cannot be extended, except by special Act of Congress. All the regulations and provisions which apply to obtaining or protecting patents for inventions, or discoveries, not inconsistent with the expressed provisions for designs apply to patents for designs.

A design is a delineation of form or figure, either plain or solid, a shape or configuration. The construction of an article in accordance with that delineation is the materialization of the conception of the design. Under the decisions in design cases, it has been held that the Act requires that the shape produced shall be the result of industry, effort, genius and expense ; and also requires that the shape, form or configuration, sought to be secured, shall also be new and original, as applied to an article of manufacture.

REISSUE.

It often occurs that a patent through inadvertence, accident or mistake, is defective, and that the inventor's rights thereunder are seriously abridged or threatened. Prior to 1832, no statute existed to correct this defect, but notwithstanding this fact, the Supreme Court of the United States, in an opinion by Chief Justice Marshall, decided that the Secretary of State had a right, where the mistake had been innocently made, to correct the error and reissue the patent. The case in question was that of Grant *vs.* Raymond (6 Peters, 218, 1832).

James Grant, in 1821, had received letters-patents of United States for an improved method of manufacturing hat bodies. He subsequently discovered that his specification was defective, and there being no law provided for reissue, he filed a petition with Hon. Henry Clay, then Secretary of State, praying that his patent be cancelled and a new one issued to him. On the advice of the Attorney-General the reissue was granted and the original patent cancelled.

Grant subsequently brought suit against an infringer to recover damages in the Circuit Court for the Southern District of New York, and obtained a verdict of $3,266.66. The defendant took an appeal to the Supreme Court of the

United States, and there Mr. Daniel Webster, who had been retained by the defendant, argued with all his ability that the Secretary of State had no right or power whatsoever to cancel the original patent and to issue a new one; he contended that our whole system of patents rested upon the statutes, and that no right or prerogative power existed in the President to issue a patent. That eminent jurist, Chief Justice Marshall, however decided that although the right of the Secretary of State to reissue was not altogether free from doubt, yet, if by an innocent mistake, the instrument introduced to secure this privilege fails in its object, the public ought not to avail itself of this mistake and to appropriate the discovery without paying the stipulated consideration. The attempt would be disreputable in an individual, and a court of equity might interpose to restrain him.

The first reissue act was passed in 1832, and between it and the date of the present Act providing for the reissue of a patent, several Acts have been passed, only slightly dissimilar in language from the present Act. Section 4916 of the Revised Statues, reads as follows:

"Whenever any patent is inoperative or invalid, by reason of a defective or insufficient specification, or by reason of the patentee claiming as his own invention or discovery more than he had a right to claim as new, if the error has arisen by inadvertence, accident or mistake, and without any fraudulent or deceptive intention, the Commissioner shall, on the surrender of such patent and the payment of the duty required by law, cause a new patent for the same invention, and in accordance with the corrected specification, to be issued."

No new matter can be introduced into the specification; where no model or drawing has been filed, amendments may be made upon satisfactory proof to the Commissioner that such new matter was a part of the original invention and was omitted by inadvertence, accident or mistake. In case of suit the new patent shall have the same effect and operation as if it had been originally filed in its corrected form.

Sometimes the defect consists in the fact that the appli-

cant claims too much, and desires to incorporate a more limited claim—sometimes he has not claimed as much as the description in his specification would warrant—sometimes the invention is defectively described.

Unreasonable delay in applying for the reissue will operate as a bar against the patentee. What is a reasonable delay? was thoroughly discussed and decided in the now celebrated case of Miller *vs.* The Brass Company (104 U. S., 352, 1881).

The doctrine here laid down is substantially that the right to obtain a broadened reissue is lost after the lapse of a long period of time between the date of the original patent and the date of filing the application for reissue, the length of time which will operate as a bar is not set down as an invariable rule. This same question was involved in numerous cases such as Johnson *vs.*Railroad Company (105 U. S. 539, 1881) Combined Patents Con. Co. *vs.* Lloyd, (11 Fed. Rep. 149, 1882) Sheriff *vs.* Fulton (11 Fed. Rep. 137. 1882). The subject of "Reissue" in all its branches and ramifications is a broad one, and is another division which cannot herein be more than cursorily treated.

DISCLAIMER.

Where a patentee has claimed more than that of which he was the original inventor or discoverer, if the part is material or substantial, and the thing occurred through inadvertence, accident or mistake, and without any fraudulent or deceptive intention, he may file a disclaimer of such parts of the thing patented as he shall not choose to hold, and his patent shall be valid for all that part which is justly his own (Sec. 4917, of the Revised Statutes).

ASSIGNMENT.

If no provision were made whereby a patentee could sell his patent, or grant licenses thereunder, his patent would be of but little value to him, if he did not desire to enter into the manufacturing business himself. Provision is made to protect both the assignor and assignee of a patent, though the law in this regard is not what it should be. Sec. 4898 provides that every patent or any interest therein

shall be assignable in law by an instrument in writing, and a grant may be made to the whole or any specified part of the United States, but the time allotted for the recording of the instrument is too long—it allows three months for record. One month would be ample. Great hardship and loss are liable to occur to the assignee under the existing laws; as an illustration.

A executes an assignment to B for which, at the date of delivery of the deed, B pays A $5,000. B has previously made a title search and has found no assignment of record; within three months from the date of the deed to B, C records an assignment from A for the same patent but executed and delivered prior to the date of the deed to B. A is financially irresponsible, and B is out of pocket $5,000. C has the title to the patent. Of course by withholding the cash consideration and the holding of the deed in escrow, etc., B may make himself safe, but settlement and its incidents are postponed, as well as vexatious delay and perhaps loss occasioned, Ample time for a deed of assignment to arrive from, say, abroad, ought to be allowed; one month would cover all possible requirements for sufficient time.

The law does not provide for the record of licenses, and consequently, record is held not to be constructive notice. This certainly should be provided for, Practically the only remedy which a licensee has for money paid for an alleged exclusive license in territory previously allotted is against the licensor—perhaps irresponsible—when, too late, he finds that the licensor had previously granted the same territorial rights to another—and perhaps after the second licensee has erected a large plant, and spent considerable sums of money for machinery.

Whenever the sole owner of a patent grants to another an undivided interest in his letters-patent the parties hold as tenants in common. Neither is obliged to account to the other for profits or royalties received—unless a special contract exists for the purpose—which makes its own law. This is frequently provided for in the assignment or by special contract.

Each may sell his rights, or assign his interests, without the consent of the other parties in interest. Many very nice questions of law have arisen upon the question of assignment, license and grant, and, in numerous recent cases, fine hair-splitting distinctions have been elaborately discussed in the decisions, especially in cases where instruments purporting to be assignments were contended not to be such, but mere licenses for lack of proper phraseology, and, in numerous cases, have been so held.

Time forbids further discussion of the subject, and deeper invasions upon your indulgence in the consideration of the "Law of Invention." If these brief papers should be the means of giving the layman some insight into this particular branch of jurisprudence the object of their author has been accomplished.

ENGINEERING PRACTICE AND EDUCATION.

By Gaetano Lanza, S. B., C. & M. E.,

Professor of Theoretical and Applied Mechanics, Massachusetts Institute of Technology.

[*Continued from vol. cxxxviii, p. 478.*]

The foregoing shows that the engineer who has to perform responsible work must not trust to guesswork, but must know the principles by means of which to determine the stresses in all parts of the machine or structure, and make his calculations in accordance with these principles. He should know the character of the experiments from which are deduced the constants he proposes to use, and he should also know enough about the tests to have an opinion as to whether they were made under such conditions as to render them applicable to the work he has in hand.

Besides this, he must see, by careful inspection and tests, that the materials used are up to standard in quality. He must draw up such specifications as will secure suitable

material, and then he must apply the necessary tests to determine whether it fulfils the specifications.

In order to do this properly he must, of course, know what tests structural material of suitable quality can be reasonably expected to fulfil, and what kinds of tests are necessary in order to be able to determine whether the material possesses the good qualities desired, and whether it is free from defects.

In order to know what conditions to insist upon as to tensile strength, ductility, capability of bending, etc., he must become familiar with the behavior of the materials under stress and strain, and hence he needs to make a careful study of the experiments that have been performed especially those made under such conditions as occur in practice.

In addition to this he must know what constitutes good workmanship, and he must take the precautions necessary to secure it. Unless these details are faithfully attended to, the result will not be what it should, even though his calculation of the stresses may have been all right, and his constants correct for good materials and workmanship.

In view of what I have said, one might be inclined to ask why disasters are not of more frequent occurrence, and why our structures and machines generally are as safe as they are.

First of all, we may observe that, once in a while, some disaster happens which cannot be prevented from attracting public attention; such as the breakage of the Bussey bridge, or the bursting of the Amoskeag fly-wheel; but, frequently when breakages happen it is not considered by the management to be conducive to their best interests to publish an account of them.

Then there are cases where prospective failure makes itself evident beforehand; in other words, the piece gives warning of structural weakness, and, before an accident happens, it is either replaced by a stronger one or else it is reinforced in some way. Naturally, such cases as these are not published and are known to but a few; for the management would not consider it to be to the advantage of their firm to have the report spread among their employés

or the outside public that the structural weakness existed. Cases of this kind have come to my notice.

Again, there are other cases where the structure or machine is not on the verge of collapse, but where the margin of safety is less than good engineering requires, and where the structural weakness shows itself in a lack of stiffness, and consequently in poor work, in the case of a machine; or in vibration or yielding in the case of a structure, as a building, or a bridge.

We must remember that the strength of a structure is the strength of its weakest part, and that adding to the strength of other parts is only a waste of material; also that adding material where it does not increase the strength is also a waste of material; so that a design which does not properly consider the necessary strength and stiffness of all the parts is not merely unsafe but is also uneconomical, and results in a waste of money.

Enough has been said to show the importance to the engineer of a thorough knowledge of the strength of materials whenever it comes into play in the design and construction of either structures or machines, and it only remains to show that these are matters that the engineer has to consider and act upon at every turn, whether he is what is commonly called a civil engineer, a mechanical engineer, a mining engineer, a metallurgical engineer or a chemical engineer. To be convinced of this, we need only consider the character of some of the duties that devolve upon the engineer, in the different kinds of works which were described in the first three lectures.

Referring next to some other matters in connection with applied mechanics, I must emphasize the importance of taking the greatest care that when the young man is studying the action of the stresses in a beam bearing a transverse load, he should understand what are the assumptions, upon which the theory is based, and also all parts of the theory. Otherwise, he is liable to be led into all sorts of erroneous conclusions. As an illustration, I may say that in my laboratory of applied mechanics, where, of course, the students are required to perform a

variety of tests of the strength and stiffness of iron, steel, wood, cement, etc., we are constantly testing the strength of full-size timber beams. Every once in a while one will break by shearing along the neutral axis or center of the depth, instead of tearing at the bottom or crushing at the top. I remember, on a certain occasion, when I called attention to this fact, that a gentleman proceeded to argue from it that there was a shearing force acting in the case of a beam which the common theory of beams did not take into account. Evidently to him the common theory of beams was only the set of formulæ most commonly recorded in the books, for he apparently was not aware that it does include a consideration of the shearing stresses.

Another illustration might be taken in the fact that the ordinary formulæ for the deflections of beams are deduced from an approximate equation, where one term has been neglected, which is small in all ordinary cases of beams in structures. By using this approximate equation in a case where the neglected term was very large, some one made out an imagined mathematical demonstration that an unbalanced rotating body going at a high speed pounds towards the light instead of the heavy side, a result manifestly absurd.

Again, if the student clearly understands all the assumptions made in deducing the formulæ, he will understand that the Gordon formula for columns is not demonstrated, depending as it does on assumptions that cannot be proved; and he will be in a more judicial frame of mind in trying to determine how to make use of the experimental knowledge on the subject that we possess up to date. Next, in regard to the theory of elasticity; this is necessary in considering certain cases of complicated stresses, and while we use it now to some extent, as in determining the strength of flat plates and of shafting, it will, I do not doubt, come more into use when we get more light experimentally on some matters connected with it. I need say nothing upon the importance of having a knowledge of the principles of friction and lubrication, and of the experimental knowledge on the subject up to date,

beyond calling to your notice that the change from a poor to a good lubricant may often make a decided difference in the size of the dividends received by the stockholders of a large concern.

The next course to receive our attention is that of Thermodynamics and Steam Engineering. It might be assumed by some that this was peculiarly the province of the so-called mechanical engineer; but if you will consider again the account of the different works of which the first three lectures treated, you will realize that, in every work of any magnitude, power is needed, and in almost all cases the power used is steam. The exceptions are those cases where the works are favorably situated for the use of water-power, and even then steam is almost always used in addition; and perhaps I ought to make another exception in the case of sailing vessels, where the wind is used. Other sources of power, or water or wind in cases other than those mentioned, are only employed for small amounts of power.

Without power all the works would have to shut down; the bridge works could not build bridges, the machine shop or manufactory or mill would have to stop, the mine could not be operated, the rolling mill could not run, the dynamos and electric motors would be idle, the paper mill, the sugar refinery, etc., would have to discontinue operations. Moreover, the expenses for power in any large concern form a very large item; they include the first cost of machinery, of necessary buildings, of coal bunkers, etc., the expenses of maintenance, including coal, water and attendance, and the expenses for repairs. It behooves the engineer, therefore, to try to realize the greatest possible economy. One of the largest items of expense, after the plant is once in operation, is coal, and any method by which he can save coal will increase the profits of the concern.

In order to accomplish this, the engineer must understand the principles of steam engineering, and the larger the works with which he is connected, and hence, the greater the quantity of money involved, the more important is it that he should have all the light possible, both from theory and from experiment, that will aid him in determining how

his engines should be designed and built, how his boilers should be designed and built, what degree of efficiency he has reason to expect with any given arrangement which he may propose to adopt. Hence, it is plain that our prospective engineer needs a thorough course in steam engineering, of which thermodynamics is merely the theoretical part; and he needs this, whatever be the kind of engineering works he may expect to be connected with, if they are to be of considerable magnitude. In deciding upon the question as to how such a course should be laid out, we shall assume that he is already familiar with valve gears, and with the rest of the mechanism of the steam engine; also assume that he has had a course on heat in his physics, and that, in this course, he has been taught the subjects of thermometry, calorimetry, and the laws of the transference of heat.

He should be taught the nature and construction of the steam engine indicator; how it is to be used; how the indicator card is taken, and what it means, and he should acquire some familiarity with interpreting the characteristic and also some of the peculiar features of indicator cards; and then he should be made familiar with the general characteristics, *i. e.*, outward characteristics, of the different types of steam engines.

Next, he should receive a thorough drill in the principles of thermodynamics. What is thermodynamics, and what kind of a course should our prospective engineer have in the subject? Thermo-dynamics is simply the mechanical theory of heat, or, in other words, the science of heat with special reference to producing motion and power.

The subject was originally developed from the standpoint of the mathematical physicist, and we have a number of treatises written from this point of view, such as that of Clausius and others. Besides the fundamental principles of the science, they take up elaborate discussions of the nature of heat, and also a large mass of applications and developments in the direction, and from the point of view, of pure science, rather than in the direction of what we need to use in the consideration and the study of the

action of the steam engine, or of other heat engines, as the gas engine, the hot air engine, etc.

Instead of this, in the course to be given to our prospective engineer, we should include a thorough treatment of the fundamental principles of the subject, a study of the laws of thermo-dynamics, Carnot's function, and the whole set of fundamental equations, and their interpretations. Then should come the applications of these fundamental principles to the gases and vapors used in practice for producing power, especially steam, and also gas and air. Then a study of the experiments that have been made, and the results of the experiments on the properties of vapors and gases; the experimental determinations of the mechanical equivalent of heat; the tables of the properties of saturated steam, as pressure, temperature, density, specific heat, latent heat, entropy, etc.; also the same for other vapors. Then a study of the laws governing the flow of fluids, both gases and vapors, through orifices and in pipes, including a consideration of the resistances and a study of the steam injector.

Then the student is prepared for a study of the behavior of steam in the cylinder of a steam engine. At this point he should be taught the modern methods of analyzing and separating the various actions of the steam that passes through the engine, and of giving to each its proper consideration; as, for example, the heat used up in work, that used up in cylinder condensation, that used up in condensation in the jackets, if there are any, the heat rejected by the engine, radiation; also the methods of studying the effects of superheated steam, etc.; all these for both single and multiple expansion engines, and, in the cases of the latter, the effects of different sizes and arrangements of receivers, the methods of proportioning the cylinders, etc.

Next, he should learn what are the requirements for a proper engine test, both when it is made for ordinary commercial purposes, and also when it is to be made in a thoroughly complete and scientific manner for the purpose of obtaining definite knowledge as to how to produce the

best and most economical results by means of a steam engine.

The day when the taking of a few indicator cards from an engine, or the making of tests in which scientific principles and scientific accuracy are neglected, and claiming that such tests can furnish information as to what the real effects of different arrangements are, is rapidly passing away, the advocates of such a course confounding themselves and each other by reaching too many contradictory conclusions by their tests.

Now, from the experimental point of view, the student should have presented to him, in a carefully systematized form, an account of such experiments as have been made, with such a degree of accuracy and such regard for scientific principles as to render them worthy of study. Of course, there will be a number of tests in this list which are not up to the scientific standards of to-day; but such a study will make the student familiar with what is the extent of our knowledge of the subject up to date, and he will be all the better able to make this study effective, by being relieved of the necessity of reading accounts of a lot of worthless tests for the sake of finding out those that are worth considering.

Then he should have a good course on steam boilers, including the construction and action of the various types in use; on the laws controlling the combustion of fuel, and the evaporation of water; on questions of heating surface, grate area, tube section, horse-power, capacity, evaporative efficiency, evaporation from and at 212°, priming or superheating, draught, quantity of air required for combustion, temperature of flue gases, size of chimney, methods of feeding, methods of determining quality of the steam; and on boiler accessories, such as gauges, water glasses, grates, stokers, feed pumps, injectors, feed water heaters, economizers, damper regulators, etc. This instruction should embrace also the requirements for a reliable and accurate evaporative test; what are the possible maximum evaporative efficiencies, and what are usual evaporative efficiencies attainable under ordinary conditions.

He should also study the more recent applications of thermo-dynamics, such as air compressors, gas engines and refrigerating machines. In these cases a lack of familiarity with the laws of thermo-dynamics on the part of the makers is very likely to make itself apparent to the user through the medium of his pocket-book, and in no case will this be more likely to be true than in the case of the refrigerating machine, either for cold storage or for the making of artificial ice, and those who are engaged in this business are very rapidly realizing this fact.

Now, when the student has finished the work referred to on the steam engine indicator, and has acquired the fundamental principles of therm-odynamics, and is studying the action of the steam in an engine, it is a proper time for him to begin work in the laboratory, by making steam engine tests, alternating his duties at each successive test until he has been drilled in performing all the different parts of the work, and in making all the necessary calculations. For this purpose a small engine is, of course, better than none, but it is much better for the education of the student if his work can be done upon an engine sufficiently large to work with an economy comparable with that found in such engines as are used in large and well-designed modern plants. Such tests made by the student himself, under the direction and guidance of the instructor, will leave a lasting impression upon his mind, and will convey information which he cannot acquire as well in any other way. Hence, it is far better to use a triple, or at least a compound engine, of sufficient size to secure a steam consumption of about fourteen or fifteen pounds of water per horse-power per hour, than to use a small single engine, where the steam consumption per horse-power per hour is as high as thirty, forty or more pounds. In making the tests no loose work should be allowed, but the student should be required to perform all the work with the greatest accuracy possible, and this accuracy should be such as to render the test thoroughly reliable from a scientific standpoint. This can be accomplished provided the instructor exercises the necessary supervision over the work.

Later in the course the student should make accurate and carefully conducted boiler tests on some large boilers. By these methods, he will be made to appreciate better the work which he is doing in the class-room and will see that it finds its application in just such work as an engineer has to do in the course of his profession. Of course, he should have to perform other sorts of experimental work with steam in the laboratory besides engine and boiler tests, but of these will be referred to later.

The whole idea of such a course as I have outlined is, as you will see, to give the student a thorough drill in the fundamental principles of the subject, and then to teach him how these principles apply to the work of the engineer, by means of both class-room and laboratory work, the deductions and developments from the fundamental principles being made in the direction of engineering work, instead of in the direction of pure science; and then, by means of this work, and also by showing him where we stand to-day in regard to the matter of reliable experimental results, to equip him as fully as possible to appreciate and to take part in the best and most scientific engineering work of the present times, and thus to be ready in the future, ever to take advantage of, and to take his part in developing, whatever progress the future may have in store for us.

Another fundamental subject is hydraulics. Our prospective engineer should understand the principles of hydrostatics and hydrodynamics; in other words, the laws governing the pressure of water, and the flow of water, whether in pipes, in open channels, through orifices or over weirs. He should also be familiar with the character and the results of such experiments as have been made upon these subjects, and should know how to conduct such experimental work.

Whatever may be the special line of engineering in which he is engaged, he is liable to have to establish a water supply, with all the necessary works, such as reservoirs, pumping engines, piping, etc.; or to build a system of sewerage, or he may find his manufactory so situated that it is advisable to take advantage of a water-power, and to

build all the necessary works, such as dams, canals, locks, sluice-ways, etc. He may have to establish river or harbor works, or, even if not these, he may have to build a wharf, a quay, or even a dock, if his works are on the water's edge. Unless he is to make a specialty of hydraulic work, he cannot, in a four years' course of engineering, afford the time to make himself master of the details of all these kinds of works, but he should become familiar with the principles stated above, and then he can afterward make a special study of part or all of these subjects.

Next comes the question as to how far electricity should be accounted a fundamental subject, and consequently one to be required of all engineering students, whatever their special lines.

It is now usually customary to require them to learn some electricity in connection with general physics, and sometimes a little more; the rest being given to students of electrical engineering only.

Whether or not a considerably larger amount should be put in the list of fundamental studies, will depend upon how far and how intimately electrical appliances come to associate themselves with the every-day work of the engineer, whatever his specialty. The probabilities are, it seems to me, that it will not be many years before we shall have to insert a much larger amount of electricity than we now do in our list of fundamental studies.

The subjects thus far enumerated are fundamental, and are necessary for our prospective engineer, whatever be the special line of engineering to which he is to devote himself. He cannot afford to do without any one of them.

In laying out, therefore, any engineering course, of whatever name, whether civil, mechanical, mining, metallurgical, electrical, or chemical engineering, we should arrange, first of all, the time necessary to give good courses in mathematics, general physics, drawing (including descriptive geometry), mechanism, applied mechanics (including, of course, strength of materials), thermo-dynamics and steam, and the general principles of hydraulics. Moreover, thorough instruction in these should not be sacrificed to any

other subjects, whether of an engineering or of a general character. In other words, the work in these subjects should be thoroughly performed, whatever else is or is not accomplished.

When this has been done, we can then, and not till then, begin to consider what other subjects should be added, and these may be classified as follows: (1) subjects of a professional nature bearing on the work of an engineer in general, whatever his specialty; (2) subjects of a professional nature, which bear directly on the special line of engineering which the course is intended to teach; (3) subjects of a non-professional character intended to broaden the field of knowledge and to impart general information; (4) subjects which fulfil partly one of these functions, and partly another.

In the first class, though respectively of very different degrees of importance, I should place (*a*) machine design, (*b*) dynamics of machinery, (*c*) metallurgy of iron, (*d*) heating and ventilation, (*e*) stereotomy, (*f*) surveying, (*g*) shop-work. How many, and which of these subjects can be added will depend upon circumstances.

Reviewing in detail the kind, of course, I have in mind under each of these heads, I will make the following remarks:

(*a*) *Machine Design.*—This course, to be of the greatest value, should take up problems of real engineering design, and should deal especially with the details. Thus the student should be made to study each separate piece, and its connection with the other pieces, to determine the forces acting upon it, and the stresses to which the piece is subject in consequence of the action of these forces, and to design the separate details in such a manner that they shall have the requisite strength and stiffness.

Of course, it is desirable, also, to have some work done on mechanism design, where the student shall have practice in adapting mechanisms to the special objects that are to be accomplished, but it is also important that he should learn that in making any such design, he must study the strength and stiffness of each separate piece of which the machine is

composed, and must be fully impressed with the facts that any one of these that is not properly designed, means a machine that is not properly constructed and may mean the total failure of the resulting mechanism.

(*b*) Under the term dynamics of machinery, I include such subjects as governors, fly-wheels, dynamometers, the action of the reciprocating parts of a steam engine, etc. I need only mention these topics to make plain their importance to any engineer.

Metallurgy of iron and heating and ventilation will, I think, also make plain their importance by a mere mention of their names.

[*To be concluded.*]

A REVIEW OF STEREO-CHEMISTRY.*

By Stewart Woodford Young.

V.1
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The old structural formula for methane represented the molecule of that substance as being constructed by placing the carbon atom at the point of intersection of the two diagonals of a square, the four corners of the square being the positions occupied by the four hydrogens. This formula (*Fig. 1*) however, conflicts with the facts when we consider the di-derivatives of methane. As is well known,

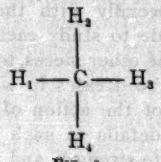


Fig. 1.

methane allows of the formation of but one series of di-derivatives. One and only one dichlormethane is known. Now, this formula allows of the existence of two series of isomeric di-derivatives, (*Fig. 2*) (*a*) representing a di-deriva-

* Read before the Chemical Section.

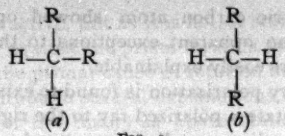


FIG. 2.

tive, in which the two substituting radicals are "neighboring," and (*b*) representing a di-derivative in which the two radicals are "opposite." A little study will show that the fact that but one series of di-derivatives is formed, cannot be explained by any plane formula We must, therefore, seek for our formula a special representation.

As early as 1860, Pasteur suggested that the property of optical activity (see later) possessed by tartaric acid might be explained if we considered the atoms composing the tartaric acid molecule as arranged in the form of a helix. Since this, many suggestions as to special formulæ have been made, but not until 1874, was there published any exhaustive treatise on the subject.

In this year Van't Hoff, and independently of him, Le Bel suggested the tetrahedron formula for methane. This formula represents the four hydrogens of methane as occupying the four apices of a tetrahedron, while the carbon occupies a position in the centre of the tetrahedron (*Fig. 3*). It is evident from a study of this formula that it permits of but one di-derivative.

A most interesting application of this formula is found in the explanation, by means of it, of that previously unaccountable phenomenon, optical isomerism. Many chemical compounds, when in solution or in fusion have the property of causing the plane of a plane-polarized ray of light to be rotated when passed through the solution or fused mass. Le Bel and Van't Hoff noticed that all such substances could be considered as derivatives of methane, in which each of the four valences was saturated by a different radical. A carbon atom possessing such properties was named "asymmetric," and Van't Hoff considered optical rotation to be conditioned by the presence of such an asymmetric carbon atom. He afterward concluded that every

such asymmetric carbon atom showed optical activity. There are some apparent exceptions to this latter statement, but all are easily explainable.

Now, rotatory polarization is found to exist in two forms. Some bodies rotate a polarized ray to the right and some to the left. Such bodies are called, respectively, dextro-rotatory and lævo-rotatory. It is found that, in a great many cases, if we have a certain compound which is dextro-rotatory, there is a lævo-rotatory compound which, in all other repects, is identical with the dextro compound. To explain the existence of dextro- and lævo-isomers, let us refer back to our formula (*Fig. 3*). If we consider H_1, H_2, H_3 and H_4 to be different radicals, it will be seen that on exchanging the position of any two of them, the formula will no longer be identical, but the one will appear as the image of the other, as it would be seen in a mirror. This affords a simple and plausible explanation of dextro- and lævo-isomers.

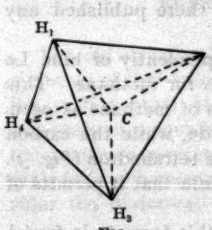
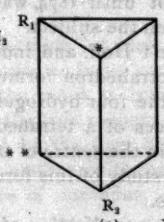


FIG. 3.



(1)

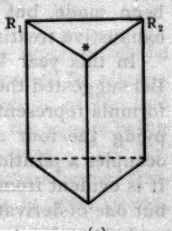


FIG. 4. (2)

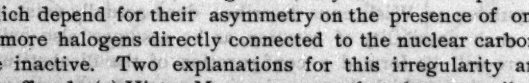
Deductions have been made as to the validity of the Ladenburg and Kekulé formulæ on the ground of optical activity. It has been pointed out that in the Ladenburg formula an ortho-di-derivative, in which the two substituting groups are different, will call for an asymmetric carbon atom (marked * in the *Fig. 4*, No. 1). But we should not expect optical activity here, it seems to me, because the carbon atom marked * * in *Fig. 4*, No. 1, is also asymmetric, but in a sense opposite to the first one. Therefore, their rotations should neutralize each other. In the case of the meta-derivative, however, there appears to be an asymmetric carbon, and only one. Therefore, we should expect such a

compound to be active, but as it is not, it stands, at present, as an argument against the prism formula for benzene.

Respecting the primal cause of rotation but little is positively known, although several explanations are offered.

The credit for the theory as above stated is due to Le Bel and Van't Hoff. Van't Hoff appears to have preceded Le Bel by a few months, but Le Bel's considerations were arrived at entirely independently. Since the first announcement, Le Bel seems to have been somewhat more active in elaborating the theory in its details.

We are now in a position to explain some apparent exceptions to the statement that every asymmetric carbon atom is optically active. (1) Racemic acid, which is isomeric with tartaric acid, contains two asymmetric carbon atoms (COOH, OH, H, C_a — C_b, H, OH, COOH), *a* and *b*, but racemic acid is inactive. However, Pasteur proved that racemic acid consists of equal molecules of dextro- and lævo-tartaric acids. Such being the case, the two equal and opposite rotations would neutralize each other and the mixture would be inactive. (2) Mesotartaric, which also contains two asymmetric carbon atoms is inactive. The inactivity of this substance is explained as being due to the fact that of the two asymmetric carbon atoms one is dextro and the other lævo. Consequently, the two neutralize each other. Letting "r" represent a dextro rotatory group and "l" a lævo rotatory group, we then have the following possible conditions for the tartartic acid isomers;



dextro-tartaric acid. | lævo-tartaric acid. | racemic acid (inactive,) | mesotartaric acid (inactive).

It is found that, in general, asymmetric compounds which depend for their asymmetry on the presence of one or more halogens directly connected to the nuclear carbon, are inactive. Two explanations for this irregularity are are offered: (a) Victor Meyer suggests that the great vibratory activity of the halogen causes it to assume alternately positions corresponding to both the dextro- and lævo-isom-

ers; (b) Easterfield's investigations on mandelic acid seem to show that the formation of asymmetric halogen compounds is accompanied by an "umlagerung" in one-half the molecules, so that the resultant product contains equal molecules of the dextro and lævo isomers.

We will now pass on to some supplementary theories, derived from that of the tetrahedron formula for methane.

Wislicenus' theories of relative rotation and favored configuration in ethane derivatives.

This theory is based upon a dynamical conception of the ethane molecules. If we consider a pair of singly-linked carbon tetrahedra we will have the condition represented in *Fig. 5*.

(In the following considerations the term "corresponding positions" is to be taken as meaning position directly under or over one another, *e. g.*, in *Fig. 5*, *a* and *a'* would be corresponding positions when *a'* was directly under *a*; or, in other words, when a line connecting *a* and *a'* was parallel to the conjoined axes of the two tetrahedra. The line connecting the two singly-linked carbon atoms, or, in other words, the line representing the direction of the two carbon valences which are used in linking the two nuclear carbon atoms, is called the axis of rotation of the molecules).

Now, Wislicenus considers that on the application of heat to a molecule of any ethane derivative, there is induced in that molecule a relative rotation of the two tetrahedra about the axis of rotation. As to Wislicenus' idea of favored configurations, it is very simply explained.

Wislicenus assumes that between like groups there exists a mutual repulsion, the degree of that repulsion depending on the degree of negativity of those groups. Assuming, now, the introduction of a negative group in each of the tetrahedra in *Fig. 5*, it will be apparent that, if such repulsion as Wislicenus describes, does actually exist, and if such possibility of rotation, as he assumes, also exists, there will be formed a configuration of the disubstituted molecule, in which the two negative groups are opposite each other, *i. e.*, as far from each other as they can get. If *b* and *c'*, in *Fig. 5*, be two negative groups, then *Fig. 5* repre-

sents the favored configuration for such a molecule. It is further apparent that the application of heat to such a mole-

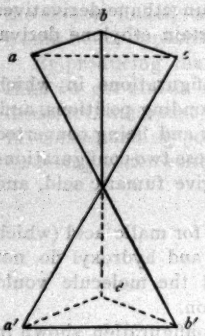


FIG. 5.

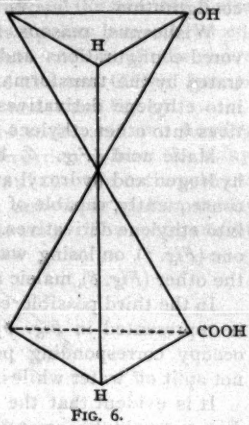


FIG. 6.

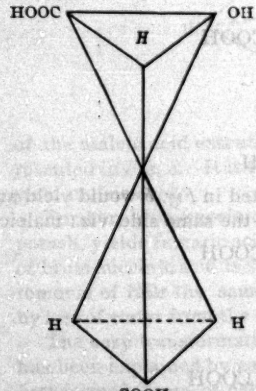


FIG. 7.

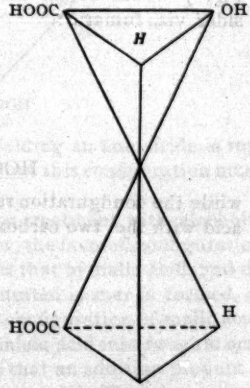


FIG. 8.

cule may overcome the directive tendencies of the two negative groups, and continuous rotation may result. On again

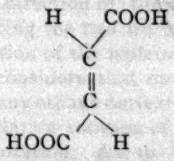
cooling to a point at which the directive tendencies preponderate, the molecule would again assume its favored configuration.

Wislicenus' reasons for assuming the existence of favored configurations and of relative rotation are best illustrated by the transformation of certain ethane derivatives into ethylene derivatives, and of certain ethylene derivatives into other ethylene derivatives.

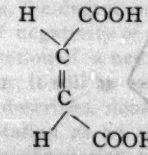
Malic acid (*Fig. 6*) has two configurations in which hydrogen and hydroxyl are in corresponding positions, and, consequently, capable of losing water and being converted into ethylene derivatives. Now, of these two configurations one (*Fig. 7*), on losing water, would give fumaric acid, and the other (*Fig. 8*), maleic acid.

In the third possible configuration for malic acid (which is represented in *Fig. 6*), hydrogen and hydroxyl do not occupy corresponding positions, and the molecule would not split off water while in that position.

It is evident that the acid from configuration shown in *Fig. 7* would be an acid with the carboxyls on opposite sides, viz.: fumaric:



while the configuration represented in *Fig. 8* would yield an acid with the two carboxyls on the same side, viz.: maleic.



Now, at the comparatively low temperature of 150°, the favored configuration of malic acid exists apparently alone, for we get, by the splitting off of water at that temperature,

fumaric acid. This would be expected from the favored configuration, which is *Fig. 7* (simply imagine the OH and its corresponding H to have split off and the two tetrahedra to have folded together until the two points previously occupied by H and OH came into contact. We would then have the doubly linked tetrahedra, and the two COOH groups would be on opposite sides of the molecule (*Fig. 9*).

By producing the anhydride of malic acid and heating this, we get maleic acid. Now, in order to form the anhydride, rotation must take place until the two carboxyls are in corresponding positions. An anhydride of this nature on losing water would yield maleic acid. The configuration

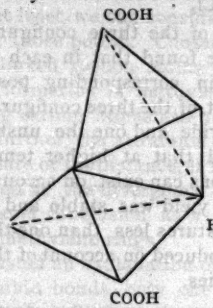


FIG. 9.

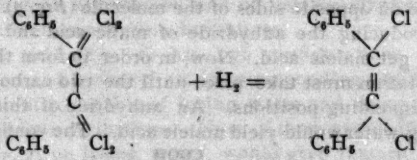
of the maleic acid essential to yielding an anhydride is represented in *Fig. 8*. It is evident that this configuration must yield maleic acid.

Further, brom-succinic acid on treatment with alcoholic potash, yields fumaric acid. Now, the favored configuration of brom-succinic acid is similar to that of malic acid, and on removal of HBr the same unsaturated isomer is formed, as by loss of water from the favored configuration of malic acid.

The easy transformation of maleic acid into fumaric acid has been explained by assuming that an addition product is first formed (brom- or chlor-succinic acid). This, then, allows of rotation to the favored configuration, where it again loses HBr and is converted, not back into maleic, but rather into fumaric acid. Many other transformations among ethylene

derivatives are most readily explained on the basis of Wislicenus' assumptions; one in particular is of interest. Tolane tetrachloride yields on reduction two dichlorides, which are isomeric and bear to one another the same relations that are found in fumaric and maleic acids.

The transformation is represented in the equation;



From a study of the three configurations of the tetrachloride, it will be found that in each there are contained chlorine atoms in corresponding positions. It will be further found that, of the three configurations, two can yield the stable dichloride and one the unstable. Accordingly, Eiloart has found that at higher temperatures, when all three configurations can exist, on account of rotation, about two-thirds of the yield was stable and one-third unstable. At lower temperatures less than one-third of the unstable dichloride was produced on account of the preponderance of directive tendencies.

V.1
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THE RELATIVE STABILITY OF METHYLENE RINGS.

Two theories have been advanced to explain the increase of stability that is noticed in methylene rings, when the number of methylene groups increases. The first is v. Baeyer's so called "strain theory." V. Baeyer considers that in doubly and trebly linked carbon compounds there are respectively two and three valences that are "strained" from their normal or ethane condition, and that on account of their strained condition they render the linking very liable to rupture. Thus ethylene derivatives are unstable, and acetylene derivatives in many cases even explosive.

In applying this thought to methylene rings it is found that although only single linkings are present, nevertheless these single linkings must be considered as diverted from their normal direction. Von Baeyer calculates this diver-

gence for trimethylene rings to be 24° 44′. In tetramethylene rings it is 9° 34′, in pentamethylene rings it is 0°44′, and in hexamethylene rings it is—5°76′. It is universally conceded that trimethylene rings are the least stable of any, tetramethylene being second in order of instability. There is some dispute as to the relative stability of penta- and hexamethylene, later investigations seeming to point to pentamethylene as the more stable.

The second of the above-mentioned theories is that due to Wunderlich, who conceived the actual shape of a carbon atom to be a tetrahedron. The points of affinity in these tetrahedra would be in the center of each face, where there is most matter, or, at least, we can consider the resultant of affinity as acting at those points. Consequently, the position of two singly-linked carbon atoms would be face to face. Now, in the formation of methylene rings the two faces of neighboring carbon atoms can no longer touch or be parallel. Since, further, the attraction of any two bodies decreases as the square of the distance, it follows that there will be less attraction as the divergence increases. Thus we arrive at the same conclusion as v. Baeyer as to the relative stability of methylene rings.

Skraup has suggested an explanation of the fact that in the breaking of double bonds, only one of the bonds is broken, and not both. Skraup accepts Wunderlich's hypothesis, and, on the basis thereof, undertakes a consideration of doubly-linked carbon atoms. Two such doubly-linked Wunderlich tetrahedra would have an edge of each in common, and their points of affinity cannot be in contact. Since they are not in contact, Skraup supposes it possible that oscillations causing alternate approach and recession between each pair are possible.

Now, two points of affinity which have separated are less saturated than when nearer together, and addition would take place at those points rather than at the positions occupied by the two points that have approached.

Thus only one bond is broken, whereas both would be affected alike if they were permanently equal. Now, since the two pairs of points *alternately* approach and recede, we

should expect equal numbers of bonds on each side of the molecules to be broken. Consequently, we get equal molecules of dextro- and lævo-tartaric acids from fumaric acid. Eiloart has suggested an objection to this idea, viz.: Since when two affinity-points recede, the attraction decreases, and when two approach, attraction increases, it is difficult to conceive why the condition of the two doubly-linked Wunderlich tetrahedra is not a condition of unstable equilibrium which the slightest displacement would cause to collapse. This objection may, in a measure, be answered by the following considerations: We have to consider, in unsaturated compounds, not only the carbon atoms themselves, but also the groups that are connected with them. Now the oscillatory displacement of two doubly-linked Wunderlich tetrahedra not only increases the attraction of the two carbon atoms, but also, by bringing nearer together the groups connected with them, causes a continual increase of repulsive force between these groups, until a point is reached at which this repulsive force exceeds the attractive force of the two carbon atoms themselves (by virtue of inertia, the two tetrahedra would be carried past the point of equilibrium), and the tetrahedra are forced back through the second phase of their oscillation.

INFLUENCE OF SPACE OCCUPIED ON STABILITY AND ON ORIENTATION OF GROUPS IN THE SUBSTITUTING OF AROMATIC HYDROCARBONS.

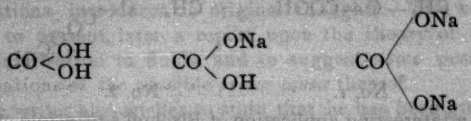
Bischoff has suggested that the cause of the instability of carbonic acid may be due to the fact that the two hydroxyls do not have room enough to perform their oscillations without conflicting with one another, and that, conflicting with one another, they split off water and carbonic acid becomes carbon dioxide and water.

$$CO{<}^{OH}_{OH} = CO_2 + H_2O.$$

He explains the much greater stability of the bicarbonates by assuming a repulsion to exist between OH and ONa which is greater than that between two OH groups.

Consequently, these two could not come near enough to conflict and the compound is stable.

The two formulæ here given represent the relative positions of the groups in H_2CO_3 $HNaCO_3$ and Na_2CO_3



Bischoff has applied this idea to many organic compounds, and has carried out exhaustive investigations upon the methyl and ethyl succinic, tartaric and glutaric acids.

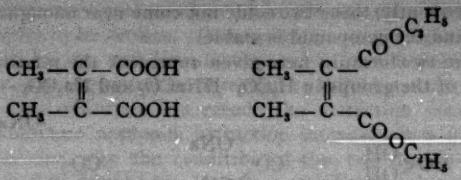
Taking the succinic acids as an example, the results of Bischoff's work are well illustrated. He found that, considering these compounds as regards their stability against anhydride formation, they could be arranged in a perfectly definite series, as follows (the arrangement being from stable to less stable):

(1) Succinic acid.
(2) Methyl-succinic acid.
(3) Di-methyl-succinic acid.
(4) Tri-methyl-succinic acid.
(5) Tetra-methyl-succinic acid.

That is invariably the introduction of a larger group for hydrogen decreases the stability against anhydride formation; because, as Bischoff puts it, there is less and less room for the oscillation of the two carboxyls, which are brought into conflict more and more readily.

A very interesting case of the influence of space occupied, is that of pyrocinchonic acid, which exists only as an anhydride, whereas its di-ethyl salt is very stable.

If the formula No. 1, following, represents pyrocinchonic acid, Bischoff's conception of the ethereal salt would be represented by No. 2.



No. 1. No. 2.

An interesting application of Bischoff's principle of space occupied has been made by Kehrmann, in connection with the orientation of substituting groups in benzene derivatives.

It is a very general statement that a group substituted in any position in benzene, renders the positions neighboring to it more readily liable to substitution. Thus the nitration of phenol gives mostly the ortho product, as would be expected. However, a small quantity of para compound is formed. This, Kehrmann says, is on account of a slight influence felt on account of lack of room about the OH groups. Thus, some of the nitro groups not being allowed to enter in the favored ortho position, are on account of repulsion between OH and NO_2 forced as far away as possible.

In nitrating nitro-benzene to the di-nitro body we get almost exclusively the meta compound. The OH in phenol shows tendencies toward prevention of ortho substitution, which are, however, comparatively slight. In nitro-benzene, on account of the much greater size of the NO_2 group over the OH group (in phenol), almost no ortho substitution is permitted and the nitro groups assume meta-positions (the same as is assumed by them in di-nitration of phenol which gives a 1, 2, 4 compound).

However, very small quantities of ortho and para di-nitro benzenes are produced on nitrating nitro-benzene, the result of the still existant tendencies to ortho substitution, with a small tendency toward para that was observed in the case of nitrating phenol.

The above report was compiled simply in order to present to the members of the Chemical Section, in the time

that could be spared to such a paper in one evening, as clear an idea as practicable of the main points covered by the field of stereo-chemical investigation. The paper is simply a compilation, and, with the exception of one or two suggestions, introduces no original thoughts. The writer hopes to present, later, a report upon the theory of rotatory polarization in fluids, and to suggest some possible explanations of the possible *primæ causæ* thereof.

The writer also wishes to state that he has been greatly aided in this compilation by the excellent articles of Victor Meyer (B. 23, 569, *Ergebnisse und Ziele der Stereochemischen Forschung*), and of A. Eiloart ("Review of Stereochemistry," *Am. Chem. Jour.*, **13**, No. 7, *et. seq.*)

THE RESISTANCE TO CORROSION OF SOME LIGHT ALUMINIUM ALLOYS.*

BY JOSEPH W. RICHARDS, PH.D.

It is well known that pure aluminium is a comparatively soft metal, and that for many machanical purposes where strength is a prime consideration, it is strengthened and hardened by being alloyed with a small proportion of some other metal, such as copper, nickel, silver, German-silver, or titanium. While pure aluminium has a tensile strength in castings of 15,000 pounds per square inch, and in sheet of 25,000 pounds, the addition of 5 per cent. of nickel or German-silver, or 2 per cent. of titanium increases the strength to 20,000–30,000 pounds in castings, and 40,000–50,000 pounds in sheet. At the same time as the strength is thus increased from 50 to 100 per cent., the specific gravity is not increased over 5 per cent.; all of these light, strong alloys being lighter than 3. An American firm making aluminium bicycles uses an alloy containing about 8 per cent. of copper and 12 per cent. of zinc, giving them castings of great rigidity.

The object of the tests about to be enumerated was to determine the relative resistance of some of these light

* Read at the stated meeting of the Chemical Section, held December 18, 1894.

alloys to corrosion. The strips of rolled metal were immersed in the following liquids:

(1) *Dilute caustic potash*, 3 per cent.—The behavior of the alloys in this solution shows their relative resistance to alkali, such as in strong soaps, etc., and shows the suitability of the alloys for laundry purposes. Solution cold.

(2) *Dilute hydrochloric acid*, 3 per cent.—This is the only acid which attacks aluminium rapidly. Solution cold.

(3) *Concentrated nitric acid.*—Shows the suitability of the alloys for replacing platinum in the Grove battery. Acid cold.

(4) *Strong acetic acid.*—Shows the resistance of the alloys against vinegar, and bears directly on the uses of the metal for pickling-kettles, etc. Solution at 60° C. = 140° F.

(5) *Strong solution of common salt.*—This shows the resistance to the agent present continually in cooking utensils. It also shows light on the suitability of aluminium for the metal cases in which artificial ice is made, a use for which its great heat conductivity would particularly fit it. Solution at 65° C. = 150° F.

(6) *Solution of carbonic acid gas.*—Aluminium has been suggested for trimmings on soda-water fountains and for the metal cups for holding soda-water glasses. The action of water charged with CO^2 would also correspond to the action of rain-water and in general to exposure out of doors. Solution at 25° C. = 77° F.

TABLE I.

RELATIVE RESISTANCE TO CORROSION. (Pure Al = 100).

	Caustic Potash.	*HCl.*	*HNO^3.*	*NaCl.*	*Acetic Acid.*	*CO^2 Water.*
3 per cent. copper	13·0	10 8	26·2	37	41·2	not corroded
3 per cent. German-silver .	1·4	4·4	9·8	78	26·0	133·3
3 per cent. nickel	5·9	3·2	11·3	31	20·7	30·8
2 per cent. titanium . . .	47·0	133·3	51·9	63	80·5	not corroded
99 per cent. aluminium .	100·0	100·0	100·0	100	100·0	100·0

TABLE II.

ACTUAL LOSSES PER DAY (in milligrams per square centimeter of surface).

	KOH.	*HCl.*	*HNO^3.*	*NaCl.*	*Acetic Acid.*	*CO^2 Water.*
3 per cent. copper	265·0	53·3	36·1	0·1	0·4	0·
3 per cent. German-silver .	1,534·4	130·6	97·7	0·05	0·6	0·01
3 per cent. nickel	580·3	180·0	83·0	0·13	0·75	0·04
2 per cent. titanium . . .	73·4	4·3	18·6	0·06	0·20	0·
99 per cent. aluminium . .	34·6	5·8	9·6	0·04	0·15	0·01

TABLE III.

TIME WHICH WOULD BE REQUIRED BY THE SOLUTION IN EATING THROUGH THE WALLS OF A VESSEL 1 MM. ($\frac{1}{25}$ inch) IN THICKNESS.

	Dilute. KOH.	*Dilute. HCl.*	*Conc. HNO^3.*	*Strong. Acet. Ac.*	*Strong. NaCl.*	*Saturated. CO^2 water.*
	Days. Hrs.	*Days. Hrs.*	*Days. Hrs.*	*Days.*	*Days.*	*Days.*
3 per cent. copper . . .	1— 2	5— 7	7—20	705	2,820	—
3 per cent. German-silver	0— 4	2— 5	2—22	467	5,600	28,000
3 per cent. nickel	0—12	1—13	3— 8	379	2,130	7,000
2 per cent. titanium . .	3—20	64— 0	14—20	1,375	4,550	—
99·9 per cent. aluminium	7—20	46—22	28— 8	1,810	6,800	27,000

Remarks on the Tables:—For bath-tubs, wash-basins, laundry-tubs, wash-boilers, and any use in which the alloys come in contact with alkali, the pure metal resists corrosion far better than any of the alloys examined. At the same time, if greater strength is required, the copper alloy stands next in suitability, and possesses the advantage of casting with less shrinkage than pure aluminium.

For purposes where free hydrochloric acid may accidentally be encountered, the titanium alloy recommends itself as far superior to the other alloys, and even to the pure metal.

For use in nitric acid, the pure metal stands first, and it would be a fair conclusion that the purer it is the greater will be its resistance. It would, therefore, be preferable to obtain the very purest aluminium for making battery plates, such as the Pittsburgh Reduction Company's 99·9 per cent. quality. A sheet of such metal one-tenth inch in thickness would bear over a month constant immersion in the concentrated acid.

In strong acetic acid the alloys all resist well, but the pure aluminium best. If it is necessary to have considerable strength, the titanium alloy is the best. The use of such alloys for steam-jacketed kettles in pickle and vinegar works; also for evaporating dishes, etc., in chemical works is of rapidly-growing importance.

In strong salt solution, pure aluminium is best, but the German-silver alloy stands highest among the alloys.

Since this alloy is of a fine color, strong and quite elastic, its use would appear advantageous in cooking utensils, but especially for the cans in ice-cream freezers and the large rectangular vessels in which artificial ice is frozen. Alumin-

ium stands next to copper and silver in heat conductivity, and its use for the last mentioned purpose would ensure a very rapid flow of heat from the contents of the cans, while the innocuity of the metal would be an additional point of superiority over the tin or galvanized-iron vessels now used.

For out-of-door exposure, as shown by the resistance to water charged with carbonic acid, the titanium or copper alloys are to be recommended. They are of about equal strength, but the copper alloy has the best color.

There are numerous purposes to which aluminium can be applied where the general requirements are fine color, strength, springiness and hardness, without particular reference to the action of the above-mentioned corroding agents. Such are, for instance, pen-holders, paper-cutters, pocket rules, match-boxes, cigar cases, combs, tongs, watch and key chains, field glasses, surveyors' instruments, mariner's sextants, and many others. For all such purposes, the German-silver alloy can be recommended as being the best adapted. Its mechanical properties have been determined by the writer, as follows:

	Cast.	*Rolled.*
Specific gravity,	2·73	2·83
	Lbs.	*Lbs.*
Elastic limit,	20,500*	40,000†
Tensile strength,	22,450*	42,040†

*Test of specimens, prepared by the writer, made on the United States testing machine at Watertown Arsenal.

†Specimens prepared by the writer, rolled hard, tested by Tinius Olsen Philadelphia.

The color of this alloy is whiter than pure aluminium; it is considerably harder, therefore, stands wear better, and in thin sheets is almost as elastic as steel.

LEHIGH UNIVERSITY, November 20, 1894.

NOTES AND COMMENTS.

A NEW PRODUCT OF THE ELECTRIC FURNACE.*—The electric smelting process, which was first developed and made manageable for industrial uses by the brothers Cowles in their now well-known electric furnace for the production of aluminium alloys, has since been studied experimentally by

* From the Secretary's monthly report, December 19, 1894.

numerous observers in the interest of pure science and the industries, and has yielded results of the most interesting nature.

The French chemist, Moissan, for example, has shown that at the enormously high temperatures which it is possible to obtain only in furnaces in which the heat of the electric arc is utilized, practically all the difficultly-reducible metals—vanadium, chromium, molybdenum, tungsten, uranium, the metals of the alkaline earths, etc.—may be de-oxidized by carbon, and obtained, under suitable conditions, in the pure state.

Even more interesting, perhaps, since it opens the door to a wide and hitherto unexplored field of chemical discovery which may eventually lead to applications of the greatest value in the industries, is the observation by various experimenters of the formation of peculiar carbon compounds, either quite new, or difficultly procurable by other methods, and which, under the conditions of intense heat, only obtainable in furnaces of this kind, are formed readily and in quantity only limited by the scale on which the operation is conducted. It will only be necessary, in proof of this statement, to refer to the silicon carbide (carborundum) of Acheson, the analogous boron carbide of Moissan, the aluminium carbide of the Cowles brothers, etc. These and other analogous compounds were previously known, but, owing to the difficulty of forming them by methods heretofore available—arising chiefly from the great intensity of temperature needed for their production—their utilization for industrial purposes was not dreamed of.

The electric furnace method has shown us that these compounds and many like them can be produced in any desired quantity and at a cost which does not prohibit their commercial application. The carborundum of Acheson is at present manufactured by the ton, and although its discovery dates only a few years back, it is already recognized in the arts as a valuable addition to the class of abrasive materials.

A more recent discovery made with the aid of the electric furnace, is that of a calcium carbide (CaC_2), which, quite apart from its scientific interest, gives promise of serving several valuable uses in the arts.

This compound, like the several others named above, is not unknown to science, having been produced for the first time, in small quantity, by the distinguished chemist Wöhler, over fifty years ago, in the course of some investigations on the preparation of acetylene (C_2H_2); and analogously constituted carbides of potassium (K_2C_2), and barium (BaC_2) have been produced by various more or less indirect and costly methods.

The discovery of the method of producing the calcium carbide directly in the electric furnace was made by Mr. Thos. L. Willson, and appears to have been an unlooked-for result obtained in the course of experiments carried on at Spray, N C., for the manufacture of alloys of aluminium and calcium.

In what follows, I shall draw freely from an admirably written descriptive article on the subject, prepared by Dr. Francis Wyatt, which appears in the impression of the *Engineering and Mining Journal*, of December 15, 1894.

While attempting to produce metallic calcium in his electric furnace, Mr. Willson succeeded in obtaining from a simple mixture of lime and carbon, subjected to the heating effect of a current of 4,000 to 5,000 amperes, a fused,

black, homogeneous mass, which on cooling became solid and brittle, and which proved upon analysis to be a very pure calcium carbide of the composition CaC_2. This substance, when dropped into water, readily decomposes liberating pure acetylene with the formation of calcium hydrate, the reaction being expressed by the formula, $CaC_2 + 2H_2O = C_2H_2 + Ca(HO)_2$.

Dr. Wyatt very appropriately refers to this contribution to organic chemistry of a plentiful and cheap source of acetylene, by so easy and simple a method of manufacturing calcium carbide, as one of the most important of the valuable resources added to the chemical industry by electrical engineers. The value of the discovery was duly appreciated by its author, and arrangements have been practically consummated for undertaking the manufacture of the carbide on the large scale.

The construction of the electrical furnace designed and patented for the purpose by Mr. Willson, does not appear to differ materially from others of the type that have preceded it, embodying merely certain changes in minor details to adapt it for yielding the best results. It may, therefore, be passed over. The same comment may apply to the operative features of the process, which Dr. Wyatt describes as "decomposing, deoxidizing, or reducing refractory metallic ores or compounds by subjecting them, while intimately commingled with an excess of finely divided carbon to the continued heat of an electric arc, the mixture being between the separated electrodes." These are essential conditions of operation in every electrical furnace. The special feature, if it may be so called, appears to be embraced in the explanation that arc shall be maintained quite close to that portion of the mixture that is immediately under treatment, while reference is made to the part played by the presence of an excess of carbon in preventing violent fluctuations of electrical resistance.

Of much more direct interest are the statements given by Dr. Wyatt of the cost of manufacturing the carbide based upon the results obtained in actual practice, and his references to the probable commercial value of this new source of acetylene.

These statements we give in the author's own language, viz.:

As the actual result of its recent practice, the Willson Aluminum Company has found that it can produce one short ton of calcium carbide from a mixture of 1,200 pounds of fine coal dust and 2,000 pounds of burnt lime, and at an expenditure of about 180 electrical horse-power per hour for twelve hours. These figures are not very far from those required by theory, and they agree very closely with those given by H. Moissan, who has also produced the carbide in an electrical furnace of his own invention. It would, therefore, seem safe to formulate the approximate cost of production somewhat as follows for both the carbide and the acetylene:

1,200 pounds coal dust, say	$2 70
2,000 pounds powdered burnt lime	4 00
180 electrical horse-power from water at, say, 50 cents per hour for 12 hours	6 00
Labor, etc.	2 50
Cost per 2,000 pounds CaC_2, say	$15 00
Cost per 2,000 pounds C_2H_2, say	$37 00

These figures would hold good, not only for the present works in North Carolina, but at any other place where very cheap water-power and equally cheap coal, lime and labor are procurable and accessible.

The specific gravity of calcium carbide is 2·22 at a temperature of 18° C., and, as may be judged from its formula, it is practically insoluble in all the ordinary reagents. Its qualities and characteristics have not been fully investigated, but Moissan has found that it may be heated in hydrogen gas, or exposed to nitrogen at 1,200°, or to the contact of silicon or boron at a bright red heat, without undergoing any change, and that it is not affected by sodium or magnesium at the softening point of glass, or by tin at a red heat. At a higher temperature than a dull red heat it alloys with iron, and this is well worth noting, because it may be of interest in the future industry of steel. It becomes incandescent in contact with chlorine, bromine and iodine at the respective temperatures of 245°, 350° and 305°. It burns in oxygen, with formation of calcium carbonate, at a dull red heat, and at 500° it becomes incandescent in sulphur vapor, and yields calcium sulphide and carbon bisulphide. Water is decomposed by it very rapidly and with evolution of pure acetylene, but its action upon steam is not so rapid, even when it is red hot, and the gas evolved is not pure acetylene, but contains free hydrogen. In dilute acids it behaves in the same way as with water, but it is only slightly attacked by fuming nitric and sulphuric acids, although ordinary sulphuric acid readily decomposes it, giving off an odor of aldehyde. Dry hydrogen chloride makes it incandescent, and the gas evolved contains a large proportion of hydrogen. With fused chromic anhydride it forms carbonic anhydride with incandescence, but with a solution of chromic acid it produces acetylene only. It is oxidized by potassium chlorate or nitrate at a red heat with incandescence, and formation of calcium carbonate. Lead peroxide oxidizes it with incandescence below a red heat, the reduced lead containing calcium, and it becomes incandescent by trituration with lead chromate at the ordinary temperature.

This rapid summary of the results of preliminary investigations would seem to strengthen the opinion already expressed, that calcium carbide chiefly claims our attention as a practically unlimited and most convenient source of pure acetylene, and there is little reason to doubt that its utilization in this direction will soon cause it to be manufactured extensively in this and other countries.

The hydrocarbon acetylene is regarded by chemists, and very justly so, as one of the most important intermediate bodies in the synthesis of organic compounds from their elements, and as one of the most interesting of the entire series. It is the only hydrocarbon that can be prepared directly from its free elements when the electric arc passes between carbon poles in an atmosphere of hydrogen, and it is worthy of consideration that this combination involves heat to the amount of 61,000 units. This tremendous energy explains why the sudden decomposition of acetylene evolves enough heat to raise the temperature to 3,000°, and why the intense molecular vibration produced by detonating a minute quantity of mercuric fulminate in 25 cubic centimetres of it causes a violent explosion, accom-

panied with production of free hydrogen and finely divided carbon. It has been hitherto produced for commercial purposes by the incomplete combustion of coal gas according to the equation: $4CH_4 + 3O_2 = 6H_2O + 2C_2H_2$, and its purification has been effected by passing it through an ammoniacal solution of cuprous chloride and subsequently decomposing the red precipitate with dilute hydrochloric acid. This is, of course, a very costly and tedious operation, and is rendered a somewhat dangerous one by the highly explosive nature of copper acetylide.

It is a colorless and highly explosive gas, of very disagreeable smell, of specific gravity 0·91. It burns with a very smoky, but much more luminous, flame than olefiant gas and undergoes complete combustion when mixed with oxygen in the proportion of 1:2½ volumes. At a temperature of 1° C. and a pressure of about 725 pounds it becomes a mobile and highly refractory liquid, much lighter than water, whereas by heating it in a sealed tube it is converted into a mixture of benzene (C_6H_6) and styrolene (C_8H_8). By passing sparks through a mixture of acetylene and nitrogen, hydrocyanic acid may be synthesized from its elementary constituents $C_2H_2 + N_2 = 2HCN$, and from this there may, of course, be produced the whole series of the cyanides and a number of other important organic bodies. If the red precipitate of cuprous acetylide in a solution of ammonia be treated with metallic zinc, nascent hydrogen is produced and ethylene or olefiant gas (C_2H_4) is formed. This in its turn can be combined with sulphuric acid to form sulphethylic acid ($C_2H_4 + H_2SO_4 = C_2H_5HSO_4$); and this, on being distilled with water, yields alcohol: $C_2H_5HSO_4 + H_2O = C_2H_6O + H_2SO_4$.

The fascinating scope for intelligent and painstaking research thus opened up in so many and so varied directions, must strike all those who are in any way interested in organic chemistry as practically boundless, and the results will undoubtedly be revolutionary. For the purpose of giving us better and cheaper illumination than the ordinary coal, water and oil gases, acetylene is already occupying much attention, and it is from this direction that results will in all probability be first made apparent. The hydrocarbons of the ethylene and acetylene series give the illuminating value to gas made from the distillation of coal; while the illuminating value of water-gas is derived from a mixture, with the non-luminous gases, of the same series of luminants obtained from the vaporization and cracking of petroleum oils. Since the power of the illuminants in any gas is in direct ratio to the relative proportion of its carbon and hydrogen, it must be plain that acetylene (C_2H_2), on account of its great proportion of carbon, must be highly diluted to prevent it from burning with a smoky flame. When, however, it is diluted by mixture in proper proportion, either with water gas or with ordinary atmospheric air, its flame is smokeless and of the utmost brilliancy and whiteness. The experiments that have been made by the Electric Gas Company have satisfactorily demonstrated that one short ton of calcium carbide will produce, by merely mixing it with water, about 10,500 cubic feet of acetylene, which, when mixed with the required amount of air, produces a gas equal in illuminating value to 100,000 cubic feet of city gas of 22 to 25 candle-power, per 5-foot standard burner. If to the estimated cost already given for the

calcium carbide there be added, say, $15 per ton for freight, incidentals and profit, the material for producing such a gas could be obtained at nearly all points for 30 cents per 1,000 cubic feet, ready for burning, and the convenience with which the calcium carbide can be packed and freighted, combined with the easy preparation of the gas itself in great or small quantities, at any time, should enable it, if not to be adopted for the common supply of large cities, to supply the requirements of country hotels and dwelling-houses and of railway cars.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, December 19, 1894.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 19, 1894.

JOSEPH M. WILSON, President, in the chair.

Present, sixty-two members and five visitors.

Additions to membership since last report, eleven.

The following nominations were made, viz.:

For *President*	(to serve one year), . . .	JOSEPH M. WILSON.
" *Vice-President*	(" three years), . . .	EDWIN J. HOUSTON.
" *Secretary*	(" one year), . . .	WM. H. WAHL.
" *Treasurer*	(" " "), . . .	SAMUEL SARTAIN.
" *Auditor*	(" three years), . . .	FRANCIS LECLERC.

For *Managers* (to serve three years).

Retiring Members.	*New Nominees.*
JOHN E. CODMAN,	WM. F. BIDDLE,
GEORGE V. CRESSON,	CHARLES H. CRAMP.
EDWIN J. HOUSTON,	ALFRED C. HARRISON,
ENOCH LEWIS,	EDWARD LONGSTRETH,
JOHN LUCAS,	SAMUEL H. NEEDLES,
SAMUEL P. SADTLER,	LAWRENCE T. PAUL,
WM. H. THORNE,	CHARLES LOUIS PRINCE,
JOHN C. TRAUTWINE, JR.,	PERCIVAL ROBERTS.

For the *Committee on Science and the Arts* (to serve three years).

Retiring Members.		*New Nominees.*
C. O. G. BILLBERG,	SAM'L R. MARSHALL,	LEWIS M. HAUPT,
L. L. CHENEY,	WM. MCDEVITT,	STACY REEVES.
JAMES CHRISTIE,	C. E. RONALDSON,	
ARTHUR L. CHURCH,	L. F. RONDINELLA,	
D. E. CROSBY,	SAMUEL SARTAIN,	
J. M. EMANUEL,	T. CARPENTER SMITH,	
JOHN L GILL, JR.,	J. LOGAN FITTS,	

The Actuary transmitted the accompanying report and recommendations of the Committee on Sections, which had been approved by the Board of Man-

agers, at the stated meeting of the Board, held Wednesday, November 14, 1894:

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, PA., November 14, 1894.

The Committee on Sections, directed by resolution of the Board of Managers to consider the expediency of sub dividing the membership of the Institute into sections, has given the subject its careful attention, and reports as follows:

The committee, at the outset, is impressed with the fact that, of the nearly two thousand persons comprising the membership of the Institute, a comparatively small proportion only is actively interested in its work. The principal reason for this circumstance, the committee believes, is to be sought in the fact that, by the present organization of the Institute, the educational and scientific work is left largely in the hands of the Secretary and the Committee on Instruction.

Chiefly on this account, members now have neither the opportunity nor the stimulus to take the initiative in scientific and technical work.

The subdivision of the membership into departments or sections representing various branches of science and the arts—each section having control of its own domestic affairs, but all subordinate to the general authority of the Institute—would, it is believed, afford the opportunity needed to induce the general body of the membership to engage actively in the cultivation of special branches of pure and applied science; and this opportunity being afforded, it is not unreasonable to expect that the needful stimulus for the prosecution of active work would come, from the feeling of responsibility and the desire to make a creditable record with which each of these departments would be permeated, but chiefly from the individual interest of members which would grow with the development of the work of each department.

The committee foresees the difficulty in the way of an early realization of such beneficent results. The most serious of these difficulties, probably, will be that of finding the right men to undertake the task of organizing the new departments from time to time, and of directing the work of each in such ways as to create the interest essential to success.

This is the vital point of the new project, and to accomplish the results aimed at, the committee believes it will be most important to proceed with deliberation, and to attempt the creation of new departments only after the most careful weighing of the probabilities of success or failure.

To the manifest difficulty of inducing the present members to adapt themselves to so great a change in the working methods of the Institute, also, there must be added the hindrance opposed by the present uninviting quarters in which we are housed and the lack of many desirable facilities.

After giving due consideration to the subject in all its aspects, however, the committee believes that the broadening of the field of usefulness of the Institute that would follow from the successful realization of a project of this kind, presents the prospect of such incontestable advantages, that a proper effort to carry it into execution should be made. Even should it prove a failure, the Institute would still be in its present position as to its scientific organization, and would consequently lose nothing in making the experiment.

The committee, in conclusion, submits the following recommendations:

"That the membership of the Institute be subdivided into sections (substantially after the pattern of the sections now in existence), which sections shall be organized from time to time, as, in the discretion of the Board of Managers, may be found expedient;

"That the expenses of the sections now in existence, or which may hereafter be organized, be assumed by the Institute and provided for in the usual manner by annual appropriations; and,

"That this committee, or a special committee appointed for the purpose, be authorized to prepare the needful amendments to the By-laws of the Institute to carry the foregoing propositions into effect."

At a special meeting of the Committee on Sections, held Wednesday, the 14th inst., at which were present Messrs. Jayne, Pemberton, Thorne and the Secretary, the foregoing report was adopted and ordered to be transmitted to the Board of Managers.

[SIGNED] H. W. JAYNE, *Chairman.*

Reported to the Board of Managers and approved Wednesday, November 14, 1894.

[SIGNED] H. L. HEYL, *Actuary.*

In accordance with the foregoing action of the Board of Managers, the following substitute for Article XI, of the By-laws, relating to the "Organization and Government of Sections," is recommended by the Board for adoption by the Institute as an amendment to the By-laws, with the object of promoting the growth and utility of the Sections:

ARTICLE XI.

ORGANIZATION AND GOVERNMENT OF SECTIONS.

SECTION 1. For the promotion and encouragement of manufactures and the mechanic arts, as well as of the sciences connected with them, members of the Franklin Institute may form sections and hold meetings in the Hall, or such other rooms as may be provided for them by the Board of Managers. These sections shall be constituted as hereinafter provided, and shall have precedence in the order of their formation.

SEC. 2. Any number of members, not less than twelve, may constitute a section.

SEC. 3. Members desiring to form a section shall make written application to that effect to the Committee on Sectional Arrangements, which committee shall report such applications, from time to time, to the Board of Managers at one of its stated meetings, with such recommendation as the committee may deem it expedient to make in each case.

An application for the formation of a section shall be made in the following form:

"The undersigned, members of the Franklin Institute, request that they may be constituted the ——— Section of the Franklin Institute."

This application, when submitted by the Committee on Sectional Arrangements, shall be considered by the Board of Managers, and, if approved by the Board, the section shall be established and the names of the petitioners shall be recorded on the minutes as the founders of that section, and shall be reported by the Board of Managers to the Institute at its next meeting. Whenever the petitioners have organized, they shall report such organization, with the names of their officers, to the Committee on Sectional Arrangements. But if they shall fail to organize such section within six months after the date of said approval, or if an established section shall fail to make a report of its proceedings to the Committee during any period of twelve months, it shall be the duty of the Committee on Sectional Arrangements to inform the Board of Managers, which may thereupon declare that such section is extinct.

SEC 4. All members of the Institute shall have the privilege of enrolling themselves, without payment of additional fees, as members of any of the sections which are now, or which may hereafter be, established in conformity with these By-laws, and such enrollments shall be reported from month to month to the secretaries of the sections designated; but no person shall be entitled to any of the privileges of

any of the sections who has not complied with the conditions of Section 3 of Article III of these By-laws.

SEC. 5. Each section shall submit to the Committee on Sectional Arrangements prior to the stated meeting of the Board of Managers in December of each year, an estimate of moneys it will require for the ensuing year, and such estimate the Committee on Sectional Arrangements shall transmit, with its recommendation, to the Board at its stated meeting in December.

SEC. 6. Each section shall elect its own officers and make its own by-laws, not inconsistent with the Charter and By-Laws of the Franklin Institute. The Institute shall not be responsible for bills contracted by any section except in conformity with the conditions prescribed in Section 4, of Article XII, of the By-laws relating to committees, nor in any event for a sum greater in any one year than the amount appropriated by the Board of Managers for the service of the section for that year.

SEC. 7. All requisitions for supplies shall be made by order upon the Actuary of the Institute.

SEC. 8. The books, papers, apparatus, specimens, models, and all other collections of each section shall be the property of the Institute, held for the use of that section. Donations of objects or books to or for any section, shall be received and reported to the Committee on Sectional Arrangements, and by this committee to the Board of Managers, as donations to the Institute for the use of that section.

SEC. 9. At the first meeting of each section it shall determine, subject to the approval of the Board of Managers, the times of its stated meetings.

SEC. 10. Papers read and lectures delivered before any section and approved by the same, shall be referred to the Committee on Publications of the Institute, and, if accepted by them, shall be published in the *Journal of the Institute*.

SEC. 11. Societies now existing, or which may hereafter be founded, for the consideration of any subjects clearly within the scope of the Franklin Institute, and which societies may desire to unite with the Franklin Institute as sections, shall furnish a list of such of their members as have declared their willingness to become members of the Institute, to the Committee on Sectional Arrangements, which committee shall transmit the same, with its recommendation, to the Board of Managers.

SEC. 12. On all points not herein provided for, each section shall be governed by the Charter, By-laws and usages of the Institute.

On Mr. Heyl's motion, the amendment was ordered to publication.

Mr. John H. Cooper read an historical sketch of the evolution of the tangential water-wheel, illustrating his remarks with a specimen of the Pelton water motor and with a number of lantern slides. (Referred for publication.)

Mr. Snedeker exhibited and described a new form of typewriting machine, called the "Duplex" typewriter, the chief peculiarity of which lies in the employment of a double bank of keys, by which it is made possible to strike and print two letters or symbols simultaneously, one with each hand.

Mr. W. N. Jennings exhibited a number of characteristic photographs of the Penn statue, recently completed in aluminum-bronze by the Tacony Iron and Metal Company, from the design of Mr. Alexander Calder. The statue is now in its appointed place, on the dome of the City Hall.

The Secretary presented his monthly report. Among the novelties shown was an engraved portrait on silver, executed by Mr. Leslie S. Marshall, of Boston. Adjourned.

WM. H. WAHL, *Secretary*.

PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. TOWNSEND, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR NOVEMBER, 1894.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 30, 1894.

GENERAL REVIEW.

The average temperature for November, 1894, 38°·2, is 2°·0 below the average [40°·2] for the past seven years.

The highest recorded temperatures occurred on the 2d and 3d, and were as follows: Pittsburgh, 74°; Johnstown, 72°; Lock Haven, 72°, and Selins Grove, 72°.

The lowest were on the 20th, 26th and 29th. Saegerstown, 6°; Shingle House, 8°; Wellsboro, 8°; Somerset, 10°; Dyberry, 10°, and Salem Corners, 10°.

From January 1, 1894, to November 30, 1894, the accumulated excess in daily mean temperature at Philadelphia was 427°; at Erie, 656°, and at Pittsburgh, 553°.

For the same period the deficiency in precipitation, in inches, at Philadelphia, was 1·56; Erie, 6·70, and Pittsburgh, 9·64.

TEMPERATURE.

	Mean Temperature.	*Mean Precipitation, Inches.*
November, 1887,	39°·2	1·80
1888,	42°·0	3·37
1889,	41°·0	6·72
1890,	41°·5	1·49
1891,	39°·6	2·65
1892,	39°·1	4·34
1893,	39°·1	2·93
1894,	38°·2	2·50

The means of the daily maximum and minimum temperatures, 46°·2 and 30°·2, respectively, give a monthly mean of 38°·2, which is 0°·9 below the corresponding month of 1893.

The average daily range was 16°·0.

Highest monthly mean, 45°·1 at Altoona.

Lowest monthly mean, 32°·0 at Wellsboro.

Highest temperature recorded during the month, 74° on the 2d at Pittsburgh.

Lowest temperature, 6° on the 26th at Saegerstown.

Greatest local monthly range, 63° at Saegerstown.

Least local monthly range, 39° at Altoona.

Greatest daily range, 48° at Drifton.

PRECIPITATION.

The average precipitation for the State, for the month, 2·50 inches, is 0·83 inches less than the average [3·33] for the last seven years.

General rains occurred on the 3d, 5th, 8th, 9th, 10th, 17th, 23d, and 30th.

The snowfall was generally light. The greatest totals in inches were Edinboro, 26·0; Cassandria, 20·0; Shingle House, 16·5; Grampian, 14·0, and Smethport, 11·0.

Very little remained on the ground at the end of the month.

The largest monthly totals of rainfall were: Warren, 3·64; Quakertown, 3·52; Mauch Chunk, 3·33; Philadelphia [Centennial Avenue], 3·33; Forks of Neshaminy, 3·28, and *Philadelphia* [Weather Bureau], 3·26.

The least were: Altoona, 0·74; Chambersburg, 1·28; Brookville, 1·39; Hollidaysburg, 1·40; State College, 1·59, and Ridgway, 1·65.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: rainy days, 9; clear days, 10; fair days, 9; cloudy days, 11.

BAROMETER.

The mean pressure for the month, 30·12, is about ·07 above the normal. At the United States Weather Bureau Stations, the highest observed was 30·76 at Harrisburg on the 29th, and the lowest 29·62 at Erie on the 3d.

MISCELLANEOUS PHENOMENA.

Hail.—Quakertown, 9th, 10th; Phœnixville, 30th.

Snow.—Hollidaysburg, 7th, 10th, 13th, 19th, 25th; Le Roy, 5th, 6th, 7th, 8th, 10th, 11th, 12th, 13th, 14th, 15th, 19th, 24th, 25th, 28th, 30th; Towanda, 5th, 6th, 7th, 8th, 11th, 19th, 24th, 25th, 28th, 29th, 30th; Quakertown, 7th, 8th, 9th, 10th, 24th, 30th; Cassandria, 5th, 6th, 7th, 10th, 11th, 13th, 14th, 19th, 24th, 25th, 28th; Johnstown, 5th, 8th, 10th, 11th, 25th, 26th, 28th; Emporium, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 13th, 14th, 19th, 24th, 25th, 28th, 30th; E. Mauch Chunk, 8th, 10th, 30th; State College, 5th, 7th, 24th; Coatesville, 9th; Phœnixville, 9th, 30th; Westtown, 9th; Lock Haven, 12th,

25th, 30th; Saegerstown, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 13th, 15th, 17th, 18th, 28th, 30th; Carlisle, 11th, 13th; Uniontown, 6th, 10th; Lebanon, 7th, 13th, 19th, 24th, 30th; Coopersburg, 8th 10th, 24th, 28th, 30th; Drifton, 8th, 11th, 30th; Wilkes-Barre, 8th, 23d, 30th; Smethport, 8th, 11th, 24th, 25th, 28th, 30th; Logania, 13th, 19th, 24th, 30th; Philadelphia [Centennial Avenue], 9th, 24th, 30th; Blooming Grove, 5th, 8th; Shingle House, 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 13th, 19th, 24th, 25th, 26th, 27th, 28th, 29th, 30th; Selins Grove, 8th, 16th, 30th: Somerset, 7th, 9th, 10th, 25th; Wellsboro, 7th, 8th, 9th, 13th, 30th; Lewisburg, 8th; Dyberry, 5th, 8th, 10th, 13th, 19th, 24th, 28th, 30th; Honesdale, 8th, 10th, 24th, 30th; South Eaton, 8th, 30th; York, 7th, 10th, 11th, 30th; Hamlinton, 5th, 8th, 9th, 10th, 13th, 18th, 19th, 28th, 30th; Greenville, 10th, 11th.

Sleet.—Cassandria, 30th; Johnstown, 30th; State College, 30th; Phœnixville, 30th; Lock Haven, 7th, 9th; Philadelphia [Centennial Avenue], 11th, 24th; Somerset, 30th; Wellsboro, 7th, 8th; York, 30th.

Aurora.—Lock Haven, 12th.

Coronæ.—Cassandria, 2d.

Solar Halo.—Le Roy, 29th.

Lunar Halo.—Carlisle, 11th.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for November, 1894.

County.	Station.	Elevation above Sea Level (feet).	Temperature.									Precipitation.				Number of Days.			Wind. Prevailing Direction.	Observers
			Mean.	Maximum.		Minimum.		Mean of Maximum.	Mean of Minimum.	Daily Range.		Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rain or Snow.	Clear.	Fair.	Cloudy.		
				Highest.	Date.	Lowest.	Date.			Mean.	Greatest.									
Allegheny,	Pittsburgh,	820	40·4	74	2	22	20, 29	48·0	32·0	16·0	30	1·80	0·3	. .	15	7	9	14	NW	O. D. Stewart, W. B.
Berks,	Hamburg,	380	39·0	68	2	26	20	46·4	31·6	14·8	35	3·06	. .	. .	11	7	13	10	NW	William Shipe.
Berks,	Reading,[2]	280	38·2	. .	. .	. .	. .	. .	. .	. .	. .	2·49	. .	. .	9	. .	. .	. .	. .	Franklin Yeager.
Blair,	Altoona,	1,181	45·1	65	3	26	29	52·8	37·4	15·4	29	1·40	. .	. .	7	. .	. .	. .	W	Dr. C. B. Dudley.
Blair,	Hollidaysburg,	947	37·9	69	2	13	20, 29	48·5	27·3	21·2	39	2·47	4·2	0·8	12	8	5	17	SW	Prof. J. A. Stewart.
Blair,		1,400	32·6	64	2	12	29	39·0	26·3	12·7	37	1·04	4·5	1·0	13	10	14	6	W	G. W. T. Warburton.
Bradford,	Le Roy,		36·0	69	2	15	20	44·0	29·1	13·7	38	3·28	. .	. .	8	4	14	6	W	Hiram E. Bull.
Bradford,	Towanda,		. .	. .	. .	. .	. .	. .	. .	. .	. .	3·55	. .	. .	12	7	9	14	NW	J. C. Hilsman.
Bucks,	Forks of Neshammy (29 days),	304	43·4	. .	. .	16	20	46·2	29·9	16·3	35	3·18	20·0	. .	16	12	4	14	NW	J. L. Hancock.
Bucks,	Quakertown (24 days),	530	38·0	68	2	13	20	40·2	30·2	10·0	27	2·55	4·5	. .	10	9	6	15	S	A. H. Boyle.
Cambria,	Cassandria	2,100	35·2	60	2	12	20	47·7	29·6	18·1	38	1·81	7·5	1·3	7	13	8	9	SW	E. C. Lorentz.
Cambria,	Johnstown,	1,184	38·6	72	2	12	20	44·1	28·6	15·5	35	3·33	5·8	2·0	7	. .	. .	. .	N	T. B. Lloyd.
Cameron,	Emporium,	1,050	36·4	66	2	16	20	45·4	28·6	16·8	35	. .	. .	. .	. .	. .	. .	. .	. .	F. C. Winternute.
Carbon,	E. Mauch Chunk,	550	37·0	65	2	13	20	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	
Centre,	State College—		36·5	65	2	16	20, 28	44·1	28·8	15·3	29	1·59	3·0	0·8	7	9	9	12	W	Prof. Wm. Frear.
	Agricultural Experiment Sta.,	1,191	36·5	65	2	20	20, 29	47·7	32·7	15·0	24	2·78	. .	. .	11	18	3	9	W	J. C. Green, D.D.S.
Chester,	West Chester,	455	40·2	66	2	17	20	49·6	29·1	20·5	34	2·73	. .	. .	8	13	8	7	W	W. T. Gordon.
Chester,	Coatesville,	380	39·4	70	2	18	20	49·4	31·2	18·2	30	2·88	. .	. .	11	16	3	11	W	B. F. Kirk.
Chester,	Kennett Square,	875	40·3	70	2	20	29	47·6	32·1	15·5	28	3·17	T	T	14	12	6	12	NW	Knowles Crosley.
Chester	Phœnixville,	190	39·8	67	2	20	29	46·6	32·5	14·1	29	2·85	T	. .	10	13	3	12	W	John D. Carter.
Chester,	Westtown (28 days),	350	39·6	67	2	18	20	49·8	27·8	12·0	28	3·04	14·0	2·0	11	7	9	14	W	Nathan Moore.
Chester,		1,450	33·8	64	2	12	20	39·8	27·8	12·0	28	1·99	2·5	1·0	10	10	2	18	W	Prof. J. A. Robb.
Clearfield,	Grampian,	560	39·0	72	2	16	20	47·7	30·4	17·3	40	. .	. .	. .	. .	. .	. .	. .	. .	
Clinton,	Lock Haven,[1]		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	Prof. J. G. Cope.
Columbia,	Bloomsburg—	500	. .	. .	. .	. .	. .	. .	. .	. .	. .	2·61	11·0	. .	14	. .	12	18	S	J. G. Apple.
	State Normal School,	1,200	34·8	69	2	6	26	43·7	26·0	17·7	40	2·63	1·0	. .	6	12	11	7	W	J. E. Pague.
Crawford,	Saegerstown,	480	39·9	70	1	19	20, 28	47·2	32·6	14·6	33	1·90	T	. .	7	10	10	10	W	F. Ridgway, W. B.
Cumberland,	Carlisle,	480	40·0	67	2	23	20	46·0	34·0	12·0	26	. .	. .	. .	. .	. .	. .	. .	. .	
Dauphin,	Harrisburg,		. .	. .	. .	. .	. .	. .	. .	. .	. .	2·82	. .	. .	. .	11	12	7	NW	Prof. S. J. Cunningham.
Delaware,	Swarthmore—		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	5	8	17	SW	C. F. Sweet.
	Swarthmore College,	361	41·0	64	2	22	20, 30	46·6	35·3	11·3	22	. .	26·0	2·0	. .	5	8	17	S	F. Wood, W. B.
	Edinboro,[2]	1,400	33·8	62	2	16	20	46·0	31·0	15·0	33	1·90	. .	. .	17	9	14	14	W	Wm. Hunt.
Erie,	Erie,	681	39·0	71	2	22	20	47·2	33·6	15·7	36	2·96	. .	. .	8	10	8	12	NW	J. C. Boggs.
Erie,	Uniontown,	1,000	41·4	66	2	21	20, 29	49·3	33·6	15·7	36	1·28	. .	. .	6	6	13	11	W	
Fayette,	Chambersburg,		39·3	68	2	18	20, 29	48·6	30·0	18·6	39	. .	. .	. .	. .	. .	. .	. .	. .	
Franklin,	Huntingdon—		. .	. .	. .	. .	. .	. .	. .	. .	. .	1·81	. .	. .	9	11	5	14	W	Prof. W. J. Swigart.
Huntingdon,	The Normal College,	650	39·0	70	2	14	20	48·6	29·4	19·2	40	. .	. .	. .	. .	. .	. .	. .	. .	
Lancaster,	Lancaster (27 days)—		. .	. .	. .	. .	. .	. .	. .	. .	. .	1·91	. .	. .	6	13	8	6	E	A. V. Heister.
	Franklin and Marshall Col'ge,	413	40·4	69	2	19	29	50·7	30·0	20·7	34	2·57	1·0	. .	7	12	9	9	SW	G. W. Hayes, C. E.
		458	39·2	67	2	19	20, 29	47·7	30·6	17·1	32	2·75	1·1	0·1	8	13	10	7	SW	Dr. M. H. Boye.
Lebanon,	Lebanon,	520	39·4	64	2	18	20	47·0	31·8	15·2	27	2·52	4·2	1·0	6	8	6	11	N	J. R. Wagner.
Lehigh,	Coopersburg,	1,683	38·2	68	3	13	19, 21	49·8	26·7	23·1	48	2·29	4·0	. .	6	7	8	15	N	A. W. Betterly.
Luzerne,	Drifton (25 days),	575	38·2	69	3	10	20	47·4	28·9	18·5	37	. .	. .	. .	. .	. .	. .	. .	W	C. H. Kemp.
Luzerne,	Wilkes-Barre,	2,000	. .	. .	. .	. .	. .	. .	. .	. .	. .	2·52	11·0	. .	9	9	9	12	SW	Armstrong & Brownell.
McKean,	Kane,	1,500	33·3	69	2	12	26	40·6	26·0	14·6	41	. .	. .	. .	. .	. .	. .	. .	. .	
McKean,	Smethport,		. .	. .	. .	. .	. .	. .	. .	. .	. .	2·47	3·0	. .	13	6	8	16	. .	Prof. S. H. Miller.
Mercer,	Greenville—		. .	. .	. .	. .	. .	. .	. .	. .	. .	2·80	. .	. .	8	15	10	5	NW	Charles Moore, D.D.S.
	Thiel College,	1,000	35·8	68	2	13	12	43·5	28·0	15·5	33	. .	. .	. .	. .	. .	. .	. .	. .	T. Merriman.
Montgomery,	Pottstown,	150	41·0	69	2	20	20	48·2	33·8	14·4	30	. .	. .	. .	. .	. .	. .	. .	. .	
Northampton,	South Bethlehem,		39·0	64	2	19	20	44·6	33·3	11·3	24	. .	. .	. .	. .	. .	. .	. .	. .	J. W. Moore.
Northampton,	Easton—		. .	. .	. .	. .	. .	. .	. .	. .	. .	2·70	. .	. .	8	9	14	7	NW	Richard Callin.
	Lafayette College,	325	38·5	62	2	18	20	45·4	31·6	13·8	30	2·64	0·8	0·3	9	13	10	7	NW	L. M. Dey, W. B.
	(Aqueduct) Logania,	367	40·5	68	2	14	29	48·1	32·9	15·2	32	3·26	T	. .	13	13	5	11	NW	John Comly.
Perry,		117	42·0	69	2	22	20	48·3	35·8	12·5	22	3·33	T	. .	12	13	5	12	NW	John Grathwohl.
Philadelphia,	U. S. Weather Bureau.	120	42·5	69	2	23	20	49·4	35·6	13·8	24	2·91	4·0	1·0	6	4	14	12	S	
Philadelphia,	1529 Centennial Avenue,		34·3	64	2	10	20	. .	. .	. .	. .	2·42	10·5	T	19	6	5	19	W	C. D. Voorhees, M.D.
Pike,	Blooming Grove,[2]		. .	. .	. .	8	29	41·8	24·8	16·0	45	2·08	3·0	2·0	5	. .	18	12	W	J. M. Boyer,
Potter,	Shingle House,	1,475	33·8	69	2	8	29	48·4	28·5	19·9	35	2·70	7·0	. .	10	2	17	11	NW	W. M. Schrock.
Snyder,	Selins Grove,	455	38·4	72	3, 4	16	22	44·1	24·2	19·9	36	3·06	8·0	1·5	10	7	7	16	NW	H. D. Deming.
Somerset,	Somerset,	2,250	34·2	66	4	10	26	. .	. .	. .	. .	. .	. .	. .	7	5	11	14	S	Prof. W. G. Owen.
Tioga,	Wellsboro,[2]	1,327	32·0	64	2	8	20	48·0†	28·7	19·3	36	1·86	1·0	. .	8	9	7	14	NW	Theodore Day.
Union,	Lewisburg (21 days),†	450	38·9†	68	2	18	20	48·0	28·7	19·3	36	2·21	7·0	2·0	7	13	9	8	W	Andrew Thompson
Wayne,	Dyberry,	1,100	33·4	68	2	10	20	41·6	25·2	16·4	41	2·18	9·0	. .	12	3	14	13	W	T. B. Orchard, M. D.
Wayne,	Honesdale,	1,000	36·6	62	2	16	20	47·3	29·8	13·5	29	2·90	7·9	. .	7	. .	. .	. .	. .	Murray Forbes.
Wayne,	(Salem Corners) Hamlinton,	1,600	34·4	68	2	10	20	41·3	27·6	13·7	31	2·45	. .	. .	. .	. .	. .	. .	. .	C. D. Ambrose.
Wayne,	(Immel Reservoir) Lycippus,	1,420	37·0	70	3	16	29	45·1	29·0	16·1	32	. .	. .	. .	. .	. .	. .	. .	. .	B. M. Hall.
Westmoreland,		1,750	. .	. .	. .	. .	. .	. .	. .	. .	. .	2·27	2·0	1·0	5	10	10	10	NW	Mrs. L. H. Grenewald.
Westmoreland,	Ligonier,	660	37·4	68	2	12	20	44·2	29·6	15·6	36	2·09	T	. .	9	18	4	8	W	
Wyoming,	South Eaton,	385	40·4	68	2	17	29	48·6	32·1	16·5	32	. .	. .	. .	. .	. .	. .	. .	. .	
York,	York,		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	

Mean temperature from maximum and minimum readings. * Extremes from dry thermometers † Mean temperatures, 7 + 2 + 9 + 9 + 4. ‡ Mean temperature 8 + 8 + 2,

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Delaware Basin.																																
Bethlehem,			.93		.81			.43		.27							.38				.10									.12		2.86
Blooming Grove,			1.94		.82			.39									.14						.20							.12		2.91
Brewers Lock,	.10		.67		.84			.31	.04	.10				.04			.38	.89			.15		.06	.07						.12		2.73
Coatesville,			.92		.85			.22									.38		.01		.19		.06							.10		2.73
Coopersburg,			.98		.71			.33		.14							.30				.18		.05							.01		2.75
Doylestown,			.73		.79		.38							.08			.31				.21		.06							.04		2.60
Dyberry,			.67		.77			.42		.03							.68						.05					.04		.15		2.21
Easton,			.40		1.20			.41		.23							.31				.13		.01							.01		2.70
Forks of Neshaminy,			.90		.80			.41	.05	.09				.03			.31	.05	.08		.34		.12							.07		3.18
Frederick,			.80		.80			.30		.11							.33				.18		.10							.08		2.69
Hamburg,			.96		.92			.34		.23							.25						.12							.24		3.06
Honesdale,			.87		.47			.50		.05							.05							.07							.17		2.18
Kennett Square,			.86		.75			.30	.06	.10				.04			.24	.03			.28		.14							.08		2.88
Lansdale,			.95		.65		.37		.22								.38				.23		.31							.06		3.17
Manch Chunk,			1.48		.95			.54		.05							.10						.07							.14		3.33
Ottsville,			.98		.59			.45	.08								.44				.15		.07							.14		3.14
Philadelphia, a†			1.89		.58			.29	.06	.10				.09			.24	.01	.01		.39		.06	.01						.13		3.46
Philadelphia, b,			1.74		.68			.31	.06	.11				.07			.27	.03	.01		.41		.10							.14		3.33
Phœnixville,			.90		.81			.49	.05	.10				.03	.01		.34	.02			.20	.02	.12	.03						.25		3.17
Point Pleasant,			.93		.85			.45							.06		.24				.21		.10							.04		2.88
Pottstown,			.76		1.00			.25	.11								.25				.18		.10							.15		2.80
Quakertown,			.84		.84			.45				•	•	•	•	.60	.46	.04			.23		.06									3.52
Reading,			.80		.70			.21		.31							.30				.03		.05	.01						.08		2.49
(Salem Corners) Hamlinton,	.10		.89		.65	.09		.50	.19	.20		.05	.01				.10				.10									.20		2.99
Seisholtzville,			.98		.89			.33		.29							.25				.11		.05							.06		2.96
Smith's Corner,			.97		.84			.44		.10				.05			.24				.28		.10							.05		3.07
Swarthmore,																																2.82
West Chester,			.80		.69			.27	.06	.10				.05			.37	.02			.22		.08							.12		2.78
Westtown,			.85		.67			.30	.07	.07		•	•	.10			.28				.25		.11							.15		2.85
Susquehanna Basin.																																
Altoona,			.18		.20	.07		.18		.03															.05					.03		0.74
(Aqueduct) Logania,			1.34		.39			.10		.09				.01			.22						.05		.09					.25		2.64
Bloomsburg,																																
Carlisle,			1.15		.95				.05					.07									.30						.10		2.63
Drifton,			1.17		.61			.30			.18						.38						.20							.10		2.34
Emporium,	.03		.53		.25			.40	.01	.16				.11	.02															.10		1.81
Gettysburg,																																
Girardville,			1.40		.80			.24									.26						.11	.06						.12		2.90
Grampian,			.38		.62		.10	.30		.45	.08			.03			.28		.03				.12							.65		3.44
Harrisburg,†			.95		.45			.02		.09							.30						.02							.07		1.90
Hollidaysburg,			.38		.28		.08	.22	.07	.05				.03			.04		.02				.09							.14		1.40
Huntingdon,	.62		.30		.42			.22		.07				.08			.04						.05							.07		1.82
Kilmer,			1.49		.43				.01	.10							.07						.13							.07		2.34
Lancaster,		.86				•	•	.03													.26		.03							.03		1.92
Lebanon,			.95		.81			.10									.38						.12	.03						.28		2.57
Le Roy,	.03		1.33		.49		.01	.27		.02	.01		.01				.15						.05					.05		.05		2.47
Lewisburg,			.85		.55			.23									.21						.03						.06	.03		1.86
Lock Haven,	.28		.80		.30			.20	.02			.10					.11						.09		.05					.30		1.99
Selins Grove,			1.26		.34			.12									.10													.06		2.08
South Eaton,			1.10		.47			.28								.12														.10		2.27
State College,			.66		.33			.22						.06									.07							.24		1.39
Towanda,			.85		.51			.20									.13						.03		.08					.10		1.94
Wellsboro,			1.75		.20		.40	.23	.15	.02				.05		.05							.08							.15		3.06
Wilkes-Barre,			1.24		.56			.19									.11						.20							.06		2.89
York,			.78		.52			.03	.20	.05							.25				.01		.08							.17		2.09

†U. S. Weather Bureau Stations. •Missing.

DURING NOVEMBER, 1894.

Total.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
	Ohio Basin.																																
2·86	Beaver Dam,			.25		.74	.25		.58		.14	.20		.05	.04			.04							.06						.33		1·98
2·92	Brookville,	.04		.08		.18	.08		.12		.20	.02	.31	.04	.07	.03		.12			.01				.04	.05	.02			.06	.03		1·86
2·73	Catawandria,			.25		.18	.20	.30		.18	.65	.20						.13						.10		.06			.10	.04	.19		3·18
2·73	Clarion,	.01		.39	.08	.22	.03	.43	.07	.15	.14	.14	.11	.14	.05	.02		.09			.03					.08	.03				.15		2·65
2·75	Confluence,	.11		.42		.42	.39	.09	.34	.06	.09	.01						.32	.14						.33						.15		2·87
2·60	Davis Island Dam,	.03		.28		.48	.10	.02	.40	.44	.09		.06	.08				.06							.10						.19		2·43
2·21	DuBois,		.03	.51				.28	.57		.31	.06	.06	.04	.04			.11							.15						.21		2·27
2·70	Elwood Junction,	.10		.30		.21	.28		.52		.13	.04	.03	.05	.03			.10							.12					.01	.12		1·88
3·28	Freeport,			.46	.05	.24	.05		.51	.02	.12	.10	.12	.10	.12	.03		.07			.02				.12	.03	.01		.01		.28		2·46
2·64	Greensboro,			.45		.38	.25	.02	.10	.08		.05						.30	.06						.08						.20		2·31
3·06	Greenville,	.08				.01	.03	.15	.04	.04	.30	.20	.03								.40				.40	.23	.30						2·47
2·18	(Ismael Reservoir)				.14																												
2·88	Lycippus,			.43		.50			.34	.06	.15							.20													.75		2·45
3·17	Johnstown,			.36		.48	.02	.30	.20	.05	.12	.04	.01					.06		.03				.20		.04	.02		.02		.40		2·55
3·33	Kane,																																
3·14	Ligonier,																																
3·26	Lock No. 4,	.04		.35		.34	.28	.07	.33	.03	.08	.03	.03		.04	.02		.15							.16						.57		2·37
3·31	Mahoning,	.08		.39		.36	.03	.07	.47	.05	.13	.06	.05	.05	.14	.04		.06							.10		.01				.80		2·03
3·17	Oil City,	.01		.39		.24	.24	.02	.24	.08	.23	.14	.05	.10	.15	.01		.06		.04	.28			.06	.07	.05	.05			.28	.11		2·28
2·88	Parker's Landing,	.04		.35	.01	.55	.01	.03	.44	.05	.24	.13	.07	.08	.12	.03		.10		.08	.03				.11	.03	.02				.18		2·64
2·80	Pittsburg,†			.45		.30	.03	.11	.29	.04	.04			.10	.01			.06		.01				.08	.01	.01		.01			.44		1·80
3·52	Ridgway,			.50		.25	.08		.19	.04	.12	.06		.04	.06			.05							.12	.02					.14		1·65
2·49	Saegerstown,			.35		.60			.20	.18	.27	.15	.20	.15		.01		.09	.10						.33	.01			.05		.03		2·61
	Saltsburg,	.06		.40		.36	.07	.01	.37	.05	.18	.08	.01	.03		.02		.12	.08						.11	.01	.02		.08		.25		2·14
2·59	Shingle House,	.08		.42	.08	.23		.05	.21	.02	.07	.15		.06	.01			.06			.01			.05	.25	.30		.20	.30		.28		2·42
2·76	Smethport,			.35		.28			.30			.15		.30										.13		.30			.20		.15		2·32
3·07	Somerset,				.30	.40	.12	.40	.10	.15	.25						.60								.23		.20				.25		2·70
2·82	Stoyestown,	.23		.79		.51	.02	.28	.17	.15		.20	.28					.22							.11				.05		.11		3·22
2·78	Uniontown,			.25		.49	.15	.30			.27							.31							.25						.47		2·96
2·85	Warren,			.38	.01	.45	.06		.14	.08	.12	.21	.10	.20	.04	.01		.72		.10	.01				.08	.04	.53	.11		.10	.01	.20	3·64
	West Newton,	.04		.35		.35	.27		.41	.05	.05	.05			.03			.09	.08							.18						.25		2·20
0·74	**Potomac Basin.**																																
2·64	Chambersburg,			.89		.20		.03			.07														.08						.07		1·98
	Lake Basin.																																
2·63	Erie,†	.05		.30	.02	.78		.01	.06	.03	.17	.10	.01		.01		.01	.08		.13					.04	.01					.09		1·90
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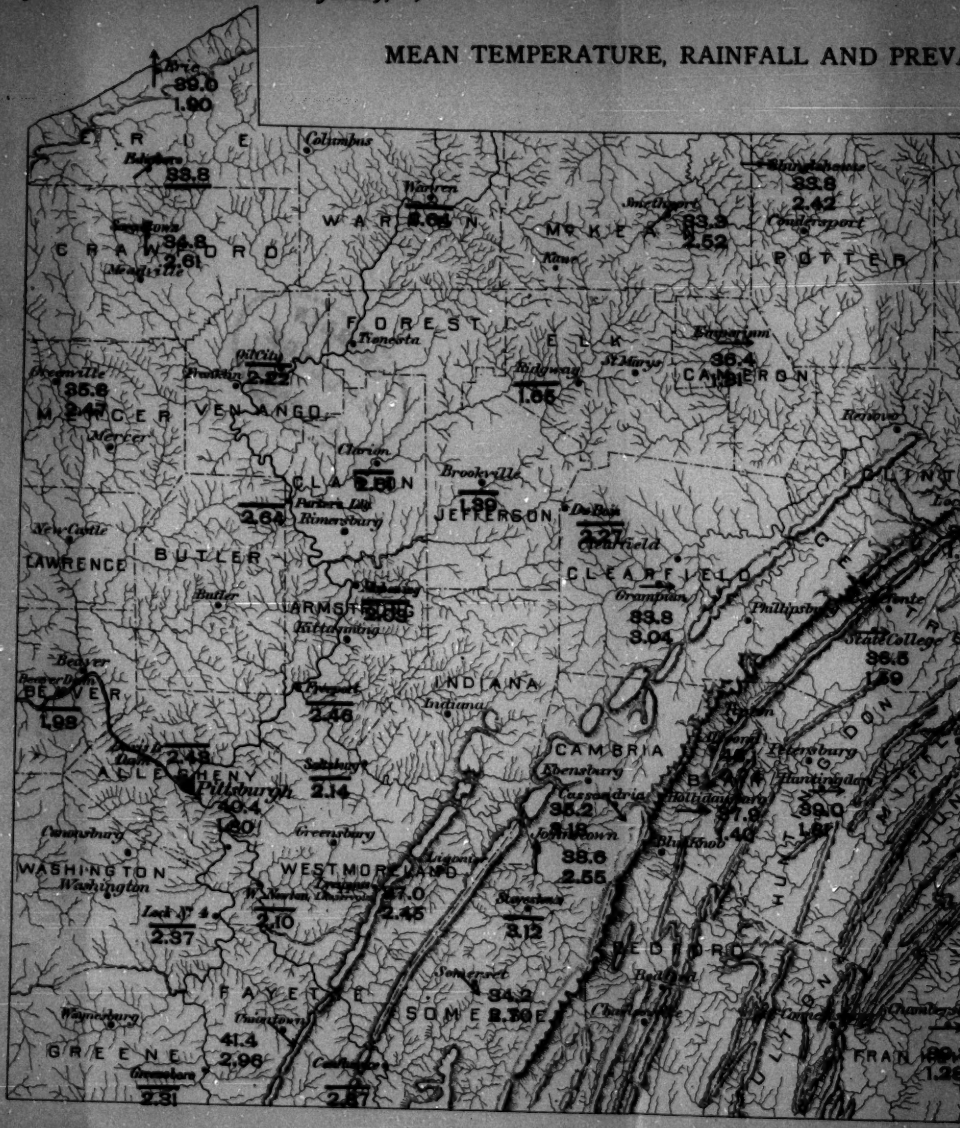
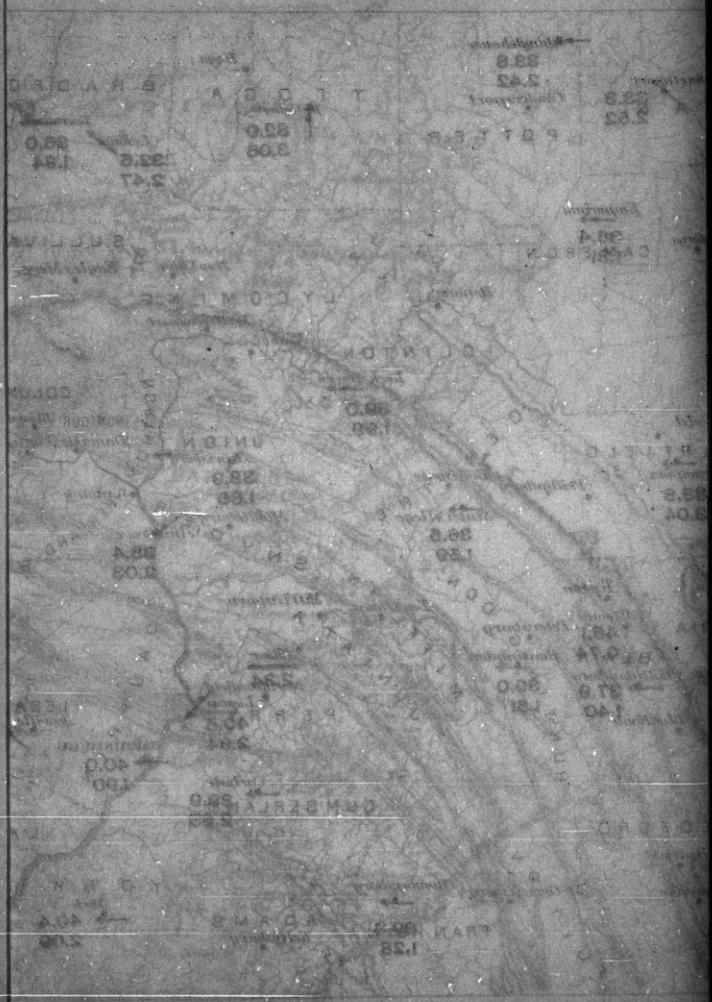
EVAILING WIND DIRECTION FOR NOVEMBER, 1894,